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PALE WESTERN CUTWORM (POROSAGROTIS ORTHOGONIA MORR.)

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INTRODUCTION

Extensive injury to grain crops by cutworms was reported from north central Montana during the period from 1915 to 1920. It was at first supposed that well-known species were responsible for the damage and the usual method of control, poisoned bran mash, was recommended. The repeated failure of this method led to a study of the situation, and from the results of numerous rearing records and the personal investigation of many infested fields it was found that the greater part of the losses was caused by the pale western cutworm (*Porosagrotis orthogonia* Morr.), a species previously not considered of economic importance in Montana. The enormous damage which it has done during the last six years, the rapidity with which it has extended its range, its unusually long period of larval feeding, its comparative freedom from parasites, and the fact that it works underground and can not be controlled by poisoned bran mash, stamp *P. orthogonia* as the most dangerous of all our western grain cutworms, not excepting even the army cutworm (*Chorizagrotis auxiliaris* Grote).

HISTORY OF THE SPECIES

The species was given its specific name in 1876 by Morrison (*15*),[2] who described it as *Agrotis orthogonia* from specimens collected at Glencoe, Nebr. In 1890 the species was placed under the genus Porosagrotis by Smith (*16, p. 129*), who also gave a description of the adult and recorded its occurrence in the following new localities: Colorado, New Mexico, Arizona, and Utah. Dyar (*3, p. 139*) lists the species and gives its range as the Rocky Mountain region. In 1905 it was reported

[1] The color plate and drawings for this article were done by Miss Helen Lund, with the remarkable accuracy characteristic of her work. Mr. K. M. King, an undergraduate assistant in 1919, conducted the rearing experiments during that year, and many of the observations recorded are based on his very complete insectary notes.

[2] Reference is made by number (italic) to "Literature cited," p. 320-321.

(doubtfully) by Dod (*2, v. 37, p. 53*) from Calgary, and in 1908 by Hampson (*9, p. 102*) from Prairie, Alberta.

The species was looked upon as a rare insect until 1911, when Gibson (*5, 6*) reported it under the name *Porosagrotis delorata* Smith as destroying large areas of wheat in southern Alberta, where one correspondent claimed to have lost 320 acres before June 21. Hewitt (*10, p. 177*) also refers to this outbreak in his annual report for 1912, and in his report (*11, p. 506*) for the following year the species is recorded along with *Euxoa ochragaster* Gn. as having destroyed between 30,000 and 35,000 acres of crop in 1912 in about the same territory where damage occurred the previous year.

An account of the insect's first appearance, its depredations during 1911 and 1912, and a brief review of the control experiments carried on the following year was given by Gibson (7) in 1914. In this article he states that *Porosagrotis delorata* Smith and *P. orthogonia* Morr. are the same and records an adult of the species as having been taken at Regina, Saskatchewan, on August 10, 1904. Hewitt (*12, p. 861–862*) states that in 1913 this cutworm caused much less damage to crops in southern Alberta than in the preceding year.

The most complete published account of the species was written by Gibson (*8, p. 30–31*) in 1915. A brief description of the larva and adult is given, together with notes on its life history and habits. In this article the common name "pale western cutworm" is used, apparently for the first time.

During the season of 1914 *Porosagrotis orthogonia* was again present in Alberta, and experiments in its control were conducted by Strickland (*17*), who found that surface applications of the bran mash were wasted but that gratifying results were secured when a molasses-and-shorts mixture was harrowed into the soil. The next account is by the same author (*18*), who gives a brief statement of the life history and makes recommendations for the control of the species by cultivation methods and the modified use of a poisoned-shorts mixture.

According to Hewitt's 1916 report (*13*), the pale western cutworm was seldom seen in 1915. Experiments, however, were conducted by Strickland which confirmed his earlier conclusions that shorts is preferable to bran and that when the soil is moist harrowing in the poison is not so advantageous as it is on dry soil.

In his 1919 annual report (*1, p. 8*) Cooley points out the habits of the species which make it such an important pest and places its control as one of the most important entomological problems in Montana.

A review of the life history of the species, descriptions of the various stages, and colored drawings of egg, larva, and adult, are given by Maxson (*14, p. 45–46*) in his work on sugar-beet insects published in 1920.

DISTRIBUTION

Published records of the occurrence of *Porosagrotis orthogonia* are as follows: Glencoe, Nebr., by Morrison (*15, p. 239*); Colorado, New Mexico, Arizona, and Utah by Smith (*16, p. 129*); Rocky Mountains by Dyar (*3, p. 139*); Calgary, Alberta, (doubtfully) by Dod (*2, 37, p. 53*); Prairie, Alberta, by Hampson (*9, p. 102*); and southern Alberta by Hewitt (*10, p. 177*), Gibson (7) and Strickland (*17*).

In Montana *Porosagrotis orthogonia* now occurs throughout the State east of the continental divide. It has been most abundant in the tier of counties which lies just east of the foothills of the main range of the Rocky Mountains and which extends from the Canadian border to within 100 miles of the southern border of the State.

Mr. E. H. Strickland has kindly given the following information on the present distribution of *Porosagrotis orthogonia* in Canada:

> Our records indicate that it is practically confined to southern Alberta, extending as far north as latitude 51° and east to longitude 108°, although it has been recorded as far as Regina, Saskatchewan. The maximum intensity, however, is confined to an area that does not extend more than 100 miles east of the Rocky Mountains.

Dr. William Barnes, of Decatur, Ill., who has an extensive collection of western noctuids, has generously furnished the following records of *Porosagrotis orthogonia* specimens in his collections: Denver, Oak Creek Canyon, Lavetta, and Alamosa, Colo.; Deming and Fort Wingate, N. Mex.; Provo, Vineyard, and Eureka, Utah; Yellowstone National Park, Wyo.; Reno, Nev.; Redington, Ariz.; and Kern County, Calif.

Mr. George M. List states that *Porosagrotis orthogonia* is fairly common at Fort Collins, Colo., 430 moths having been taken at a trap during the season of 1920.

To Mr. C. N. Ainslie, of the Bureau of Entomology, United States Department of Agriculture, we are indebted for a record of 63 *Porosagrotis orthogonia* moths reared from a shipment of larvæ from Dickinson, N. Dak., on June 10, 1920.

From the foregoing records it is evident that *Porosagrotis orthogonia* occurs at least in scattering numbers throughout the southwestern and northwestern States with the possible exceptions of Oregon, Washington, and Idaho, where as yet it has not been collected. Correspondence with entomologists throughout the territory where *P. orthogonia* has been recorded indicates that it has never been of economic importance outside of the heavily infested areas in Montana and Canada.

METHODS OF STUDYING

IN THE INSECTARY

Larvæ were reared in individual tin boxes 1.5 inches in diameter. The bottom of each box was covered with filter paper which was slightly moistened at each feeding. This prolonged the freshness of the wheat

and dandelion which were used as food, and the cans could be easily cleaned by replacing the filter paper whenever it became soiled.

Pupæ were placed in moist, well-pulverized soil in individual glass vials 1 inch in diameter and 4 inches deep. Each vial was filled to a depth of 2 inches with well-firmed soil in which a round hole 1 inch deep was punched to receive the pupa, which was placed in it with the anterior end uppermost. A small twig was placed in each vial so that the moth upon emerging could hang from it and allow the wings to expand. The vials were closed by cheesecloth held in place by rubber bands. The best results were obtained by keeping the pupæ in uniformly moist and mellow dirt. Extreme dryness or excessive moisture often resulted in the death of the pupæ. Uniform moisture conditions were more easily obtained by allowing water to run slowly down the side of the tube instead of flooding it over the surface of the soil.

After the moths emerged they were placed in wire screen covered tin cans 3.5 inches in diameter and 2.5 inches deep. An inch of moist soil was kept in the bottom of the cans, and alfalfa or clover blossoms were added each day for the moths to feed upon (Pl. 30, A) and to hide under. Cutworm moths of all kinds seem very contented in these cans, and with *Porosagrotis orthogonia* no difficulty was encountered in getting the females to mate and lay eggs.

Eggs were placed on filter paper in pint Mason jars with the caps lightly screwed down. A few drops of water were placed on the filter paper from time to time to provide the proper amount of humidity.

IN THE FIELD

A very good opportunity to watch the development of this insect under natural conditions was afforded in a heavily infested field at Wilsall, Mont., in 1919. This field was first examined on May 1 and was visited several times a month all summer. Many fields in other parts of the State were also visited, but that at Wilsall was the only one where *Porosagrotis orthogonia* was followed through all stages of its development. During the summer of 1920 a temporary field station was established at Willow Creek, Mont., in a district where thousands of acres of wheat had been destroyed during May and June. Moths appeared in large numbers during August and September and were under observation at all hours, both day and night. Special attention was given to the egg-laying habits, and for this purpose two observation cages were set up. The cages were 2-foot cubes with screen wire sides and solid metal tops. They were placed over sunflower plants, and the ground inside the cages was covered with soft dirt, stubble, clods, baked earth, and green plants, thus offering the moths nearly all the natural conditions of the neighborhood. Experiments with trap lights were also carried on at the Willow Creek field station.

SEASONAL HISTORY AND HABITS

DURATION OF EGG-LAYING PERIOD

During the season of 1919 the eggs were found to be well developed in the ovaries when the female moth first emerged, and egg laying began and was completed within a short time under insectary conditions. The first eggs were obtained from reared moths on August 17, the average period between emergence and the beginning of egg laying being four days. Moths collected in the field on August 26, which appeared to have just emerged, laid numerous eggs the following day and continued to lay until September 9.

In 1920 no records were available from reared moths, but a study of moths in the field seemed to indicate that the eggs that season were not fully developed when the moths first emerged. Thus out of 35 moths examined on August 24 only one had well-developed eggs in the ovaries. On September 1 many moths were found with the ovaries filled with well-developed eggs. These moths were mostly badly rubbed specimens, indicating that they had probably emerged some little time before.

Our field observations show that the height of the egg-laying period is during the last week in August and the first week in September. Eggs in smaller numbers may be laid during the first three weeks in August and as late as October 1.

WHERE EGGS ARE LAID

The first eggs obtained were from moths confined in tin rearing cans. When the soil in the cans was dry and light most of the eggs were placed from ¼ inch to 1 inch below the surface and could be found only by careful searching. When the soil was hard and lumpy eggs were scattered about on the surface and could be easily seen. In the rearing cans the eggs were not always laid in the soil. Many of them were placed on the stems, leaves, and flowers of alfalfa, and frequently scattering eggs were found on the sides of the cans or on the screen covers. Thus out of 243 eggs found in one can, 180 were found in the soil, 62 were found on the stems, leaves, and flowers of alfalfa, and 1 was found on the side of the can. Some were laid singly and others were in clumps of 2, 3, or 4, and sometimes as many as 40.

In outdoor cages, where a variety of soil conditions and various kinds of vegetation were available, eggs were laid only in loose, dry dirt.

Under field conditions the eggs are very difficult to find, and the only ones we have ever found were secured by carefully examining the soil at the exact spots where females were seen in the act of egg laying. Eggs are found most frequently in loose, mellow dirt from ¼ to ½ inch below the surface. This is an important point, and will be discussed later in connection with the habits of the moths and from the standpoint of control methods.

NUMBER OF EGGS

The only females upon which we have complete records are five moths reared and mated in the insectary. They averaged 315 eggs, the lowest number per moth being 248 and the highest 453. Ten moths brought in from the field averaged 132 eggs, but these had probably laid numerous eggs before they were caught. Under normal field conditions the average number per female is probably between 300 and 400. The records of the individual moths are shown in Tables I and II.

TABLE I.—*Time between emergence and egg laying, length of egg-laying period, and number of eggs laid by reared specimens of Porosagrotis orthogonia*

Moth No.	August, 1919.																			Eggs in ovaries at death.	Total number eggs.
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		
1	E	....	....	....	....	243	D5	....	....	....	....	....	....	....	....	....	....	....	....	0	248
2	E	....	....	....	9	D	....	....	....	....	....	....	....	....	....	....	....	....	....	249	258
3	....	....	....	....	....	E	....	88	45	96	54	D	....	....	....	....	....	....	....	0	283
4	....	....	....	....	....	E	....	....	....	66	251	25	26	75	D	....	....	....	....	0	453
5	....	....	....	....	....	E	....	....	....	305	2	12	....	....	12	....	....	....	....	2	333

E=emerged. D=dead.
Average period between emergence and egg laying..... 4 days.
Average period of egg laying..... 3 to 4 days.
Average number of eggs..... 315.

TABLE II.—*Period of egg laying and number of eggs laid by Porosagrotis orthogonia moths brought in from the field and kept in rearing boxes*

Moth No.	August.						September.							Eggs in ovaries at death.	Total number eggs.
	26	27	28	29	30	31	1	2	3	4	5	6	7		
1	Caught	....	....	....	....	63	D 100	....	....	....	....	....	....	4	167
2	....do	....	....	....	....	....	D 83	....	....	....	....	....	....	91	116
3	....do	22	74	43	....	....	45	D	....	....	....	....	....	0	184
4	....do	2	5	3	4	....	2	D 3	....	....	....	....	....	88	107
5	....do	....	....	....	....	....	6	D 3	....	....	....	....	....	103	112
6	....do	....	4	56	25	....	15	D 14	....	....	....	....	....	20	134
7	....do	20	35	15	30	12	6	D 8	....	....	....	....	....	1	127
8	....do	....	26	20	32	22	26	....	D	....	....	....	....	0	116
9	....do	....	....	....	....	....	....	36	44	D 26	....	....	....	0	106
10	....do	....	....	....	....	....	....	....	....	....	D	....	....	152	152

D=dead.
Average period of egg laying..... 3 to 4 days.
Average number of eggs..... 132.

DURATION OF EGG STAGE

The length of the egg stage is exceedingly variable, depending largely upon moisture conditions. It may be as short as 11 days or may extend over several months. Eggs laid in the insectary August 19 hatched August 30. On September 30 several newly hatched larvæ were found

at Wilsall. Hundreds of eggs were laid in the breeding cans during the last week in August and the first week in September, but with the exception of three larvæ which hatched August 30 no eggs hatched unless they were placed in a very humid atmosphere. The larvæ mature within the eggs in from 10 to 20 days and may remain for months in this condition, waiting merely for proper moisture conditions to allow them to break through the eggshell. Examples of this may be of interest. Moth number 1427–G laid 160 eggs on August 24 and 25. These were placed on a piece of filter paper in a Mason jar. They were allowed to stand in the laboratory for 10 days and were then placed in an incubator and held at day temperature of 80° F. and night temperature of 60°. At the end of three weeks practically all the eggs had darkened, and the black heads of the young cutworms could be seen through the eggshells, but none had hatched. On October 4 a few drops of water were added to the filter paper, and when the jar was opened 24 hours later 70 larvæ were found to have hatched. On October 11 water was again added to this jar, and 40 more larvæ hatched out.

On October 27 a few drops of water were added to another jar of 62 eggs which were laid August 29. In two hours 8 larvæ had hatched, but no more hatched during the next six hours. Twenty-four hours later all of the eggs had hatched. On October 27 moisture was added to eggs that had been kept in the greenhouse since August 30, and in two hours many of them had hatched. On this same date one of these eggs was placed on a block of plaster of Paris, and water was slowly dropped upon it from a medicine dropper. At the second drop the larva began to move within the egg. Soon it began to move its mandibles and after several attempts the eggshell was punctured, and within 30 minutes after the first drop of water was added the larva was free from the shell and actively moving about. On November 20 eggs that were laid August 30 and had been kept for a month in a small tin can on a shelf directly over a radiator were examined, and living larvæ were removed from them by carefully breaking the eggshells with fine needles.

On November 1 twenty eggs which were laid on August 29 and had been kept indoors were placed in two small wooden boxes and buried in a pail of damp sand. The pail was set on the ground, outdoors, where it was covered with snow practically all winter. The eggs were examined once a month, but none hatched until the second week in April when all the eggs were found to have hatched and the larvæ were alive and vigorous.

From our studies of the egg it would appear that if there is sufficient moisture and proper temperature condition the majority of the eggs will hatch in the fall, while if it is unusually dry or cold weather starts early the eggs will not hatch until the following spring. Strickland (*18*) found eggs on frozen ground December 3, which would indicate that in Canada some of the eggs at least do not hatch until spring.

FIRST APPEARANCE OF LARVÆ

Larvæ may appear in the fall. This is proved by the fact that three larvæ were found at Wilsall on September 30 and that larvæ hatched in the rearing boxes during October and November whenever sufficient moisture was added. Large numbers of larvæ must have hatched at Wilsall during the fall of 1918, for as soon as the snow left the ground the following spring fourth- and fifth- instar larvæ were found in large numbers. We have no records of injury to wheat during the fall months, but it seems quite probable that in years when there is considerable moisture and mild weather during October and November great damage may be done.

The larvæ begin to feed shortly after the wheat begins to grow in the spring. In 1919 at Wilsall 80 acres of winter wheat were completely destroyed by May 1, which indicates that the worms must have been active 10 days or 2 weeks previous to that date.

In 1921 at Willow Creek first-instar larvæ were found on March 3. The weather had been warm for about a week, and winter wheat was starting to grow again. No larger larvæ could be found, and it seemed as though the very small first-instar larvæ must have just hatched.

PERIOD OF LARVAL FEEDING

One of the reasons why *Porosagrotis orthogonia* is such a dangerous insect is the unusually long period of heavy larval feeding which extends until the middle of June or even to July 10 in the case of late-hatched specimens. Judging from the reports of injury received, the larvæ attract most attention during the month of May and the first two weeks in June, differing decidedly in this respect from *Chorizagrotis auxiliaris*, which generally has reached the height of its destructiveness by April 15 and has practically disappeared by May 1.

The length of the larval stage as determined for 20 larvæ, 5 from each of 4 parent moths, under insectary conditions varied from 62 to 151 days and averaged 118 days, as shown in Table III.

All of the larvæ were kept under very similar conditions, and no reason has been found for the wide variation. They were always fed at the same time and were kept on one tray in individual rearing boxes, thus giving practically identical conditions of moisture, temperature, and food. In spite of this similarity of conditions we find that larva 21e pupated 62 days after hatching from the egg, while larva 21d from the same parent and from the same egg cluster took 124 days, or just twice as long, to reach the same stage of development. The number of instars was also found to vary. Thus the number of larval instars for the five larvæ from each of the moths was as follows: Moth 21—four had 7 instars and one had 8; moth D—all five passed through 8 instars; moth 42—two had 7 instars and three had 8; moth 24—one had 7 instars and

four had 8. According to the rearing records of other larvæ than those shown in the table, several individuals passed through 9 larval instars and one passed through 10. Eight instars, however, is the usual number and the minimum is 7.

TABLE III.—*Duration of larval instars of Porosagrotis orthogonia under insectary conditions*

Larva record No.	Number of days in each instar.								Number of days in larval stage.
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	
21a	9	5	8	8	12	13	44	.....	99
21b	11	6	7	9	10	13	29	.....	85
21c	12	6	8	8	14	18	32	.....	98
21d	12	9	11	9	9	13	16	45	124
21e	9	7	8	7	11	17	14	.....	62
Da	12	9	10	9	11	13	14	37	125
Db	13	9	10	7	11	9	14	48	121
Dc	12	10	7	13	9	16	21	63	151
Dd	12	7	9	10	10	16	16	45	125
De	13	9	12	14	17	15	19	51	150
42a	11	8	12	10	11	14	25	32	123
42b	10	5	9	10	9	20	41	.....	104
42c	14	10	10	9	18	17	34	.....	112
42d	12	8	11	10	12	12	14	33	112
42e	13	11	7	10	12	13	20	33	119
Ma	9	6	8	10	10	9	21	75	148
Mb	7	7	10	15	13	18	18	56	144
Mc	13	9	9	9	9	16	18	65	148
Md	13	12	12	10	9	14	18	43	131
Me	7	7	10	10	10	13	26	.....	83
Average	11.2	8	9.4	9.8	11.3	14.4	22.6	29.6	118

FEEDING HABITS OF LARVA

The larva differs from that of most cutworms in its feeding habit in that it almost invariably attacks the plant below the surface of the ground. The most frequent type of injury is the eating away of the central stem and its surrounding sheaths from ½ inch to 1 inch below the surface of the ground. In many instances the stem is severed and the lower part not eaten, and frequently it is only slightly chewed into before the worm moves on to another plant. Even slight injury to the underground portion of the central stem usually results in the death of the plant. A very small portion of each plant is actually eaten by this cutworm, and its capacity for destruction is thus greatly increased. The first indication of injury is the presence of wilting or dried plants which can be easily lifted out of the soil without bringing the roots. The destruction of grain that is just pushing through the ground is particularly rapid, one worm being able to cut off plant after plant in quick succession. The worm usually moves along the drill row, taking each plant as it goes (Pl. 30, D). Where one crop has been destroyed and

the land has been reseeded the worms often attack sprouting grain and sometimes even gnaw into the kernels before they germinate.

The larvæ feed during both day and night. Freshly cut plants have been found repeatedly during the day and cutworms have been found with their heads inside the sheath of the plant in the act of feeding on the central stem. In the rearing boxes no difference could be noticed between the amount of day and of night feeding.

According to observations made by Strickland and reported by Gibson (7) it is the habit of the larva—

> to travel over the surface of the soil and when a suitable plant for attack is found it immediately burrows and feeds just below the surface.

In our observations we have never witnessed this habit. Considerable time has been spent during the late afternoon and evening in heavily infested fields, and except in rare instances we have never seen *Porosagrotis orthogonia* larvæ above ground. On the other hand, we have closely examined hundreds of newly attacked plants where there was no sign that the soil had been disturbed at the surface by the burrowing of the larva. In order to find out whether the worms would work from one plant to another without coming to the surface, wheat seedlings were started 3 inches apart in a flat in the greenhouse, and when the wheat was up about 1 inch 12 half-grown cutworms were placed in one end of the flat. At the same time a line of plaster of Paris was placed across the center of the flat so that any traveling of the worms over the surface at the center would be indicated by lines through the plaster of Paris. The seedlings at the end of the flat where the worms were introduced were immediately attacked, and within a week all of the seedlings in the flat had been cut off below the surface of the soil and without any indication that any of the larvæ had crossed the plaster of Paris line.

If it were the natural habit of *Porosagrotis orthogonia* to travel over the surface of the ground in getting from plant to plant, it would come in contact with poisoned bran mash scattered on the ground, and it seems as if there would be no difficulty in controlling it by the ordinary methods. The fact that poisoned bran mash is useless against *Porosagrotis orthogonia*, together with our field and insectary observations, leads us to believe that it very rarely comes to the surface in getting from one plant to another but instead moves underground, generally along the drill row.

We have received occasional reports from farmers stating that pale western cutworms had been seen feeding above ground during and immediately following rains, but only one instance of this kind has come under our own observation. This was at Willow Creek on June 27, 1920. A light thunder shower at 6.30 p. m. cooled the air and wet the ground to the depth of 1 inch. As soon as the storm was over, numerous cutworms were seen crawling over the surface in a wheat field that

was known to be badly infested with *Porosagrotis orthogonia*. It was estimated that about 50 per cent of the total number of cutworms in the soil were on the surface at any one time. They appeared in greatest numbers in the spots where the grain had previously been cut off. At first they merely wandered about over the surface, but later on, as it became dark, they started feeding. Observations were continued until 11 p. m., at which time the worms were still moving about and feeding upon the leaves of wheat and grass. At 5 a. m. the next morning a few worms still remained on the surface, but all disappeared as the sun came up. The soil around stray wheat plants was noticeably stirred up where the worms had come up and gone down. That this habit of feeding above ground is not a common one is shown by the fact that only in rare instances have we ever found any injury to that part of the grain plant which is above the ground, and in such cases there was always some doubt as to whether the injury might not have been done by some other species.

LARVÆ DO NOT LEAVE FIELDS AFTER GRAIN IS DESTROYED

Another unusual habit of *Porosagrotis orthogonia* is that it seldom migrates even though its food supply becomes exhausted. If, in following along the drill row, it fails to find a plant within a few feet, it simply remains where it is, perhaps for several weeks, without feeding or growing to any extent. In fields that are only partially infested the injury shows up as scattered bare spots, and in such places the larvæ do concentrate along the edges of the standing grain, but we have never known them to migrate more than a few rods. This habit of remaining in the fields where grain has been destroyed has a very important bearing on farm practice, as will be shown by the following example: Eighty acres of winter wheat at Wilsall in 1919 were completely destroyed by May 1, the ground being left entirely bare. The field was reseeded to spring wheat the second week in May. On May 24 the grain was just coming through the ground and was being rapidly cut off by cutworms which had remained in the field since the winter wheat had been destroyed, some three weeks before. The worms continued to feed for several weeks and destroyed all the spring wheat.

The ability to go for a long time without feeding was well shown by a half-grown larva which remained in a rearing can for 12 weeks without food and was then fed and reared to maturity.

FOOD PLANTS

In Montana this cutworm has been most commonly found feeding upon winter and spring wheat. Oats, barley, rye, flax, and alfalfa have also been attacked. In the insectary, larvæ have fed readily and grown rapidly upon dandelion. In Canada, Gibson reports *Porosagrotis*

orthogonia larvæ as feeding upon fall and spring wheat, oats, barley, flax, beets, onions, cabbages and carrots.

PERIOD OF INACTIVITY BEFORE PUPATION

Although *Porosagrotis orthogonia* larvæ are mature and have practically ceased feeding by the middle of June they do not pupate until nearly a month later. During this period they occasionally feed slightly, but for the most part they remain in a semidormant condition, gradually turning whitish in color and shrinking in size just previous to pupation. This was noticed both in the field and under insectary conditions. Notes taken at Wilsall June 20, 1919, state that on that date cutworms were decreasing in numbers and were nearly all full grown. This field was visited again on July 4, when many whitish larvæ were found, some of which had formed earthen cells, but no pupæ were found in a two-hour search.

Records kept on 75 larvæ in the insectary showed an average period of 20 days of complete inactivity previous to pupation and a period of 26 days in which only very slight feeding took place.

PUPAL PERIOD

Pupation generally takes place about the middle of July. Out of 80 specimens collected as larvæ at Wilsall in May, 1919, and reared to adults in the insectary, the average date of pupation was July 19, the earliest date July 2 and the latest August 11. This checked out almost exactly with conditions in the field at Wilsall.

About a month is spent in the pupal stage. The average length of pupal period of 80 specimens was 29¼ days, the shortest 21 days and the longest 40 days.

The pupæ are protected by a cemented earthen cell and are usually found at a depth of 3 to 4 inches in the soil beneath the plants where they last fed.

SEASONAL ABUNDANCE OF ADULTS

The earliest emergence of *Porosagrotis orthogonia* moths which we have on record is July 31, although Gibson (*8, p. 30–31*) reports the emergence of a moth of this species on July 19. In general, the period of greatest abundance is during the last two weeks in August and the first week in September.

The field at Wilsall where *Porosagrotis orthogonia* larvæ destroyed two seedings of wheat during May and June, 1919, was searched for moths on August 7, but none could be found. A trap light was run until midnight on this date, and not a moth of this species was taken. On August 26 the field was again visited, and numerous moths were found during the day, and at night they came to trap lights by the thousands. The majority of the moths taken at this time were in prime condition and

looked as though they had just emerged. One week later the number of moths was greatly reduced; they were difficult to find during the day, and very few came to lights at night. On September 30 an entire day was spent in searching the same field, but not a moth could be found. The owner of the field had been disking and drilling throughout the month of September and during the first half of the month had frequently seen moths fly up as the ground was disturbed but had seen none after September 15.

Seventy-five larvæ collected in this field May 1 and reared in the insectary at Bozeman emerged as adults on the dates shown in Table IV. In 1920 at Willow Creek the first moth was caught on August 9, the heaviest flight was from August 19 to 24, and several moths were seen as late as October 8.

TABLE IV.—*Dates of emergence of Porosagrotis orthogonia moths in 1919*

Date.	Number of moths.	Date.	Number of moths.
July 31	1	Aug. 17	4
Aug. 4	3	18	13
5	1	19	3
6	1	20	2
7	2	22	5
8	2	23	5
9	1	24	4
10	2	25	4
12	1	26	2
13	1	27	1
14	4	28	1
15	3	31	1
16	6	Sept. 1	2

EGG-LAYING HABITS

Egg laying was first witnessed at Willow Creek in 1920. Several gravid females were placed in outdoor observation cages in which a variety of soil conditions and vegetation was offered and were closely watched for several days. On the afternoon of September 4, at 4.45, one of these females was seen laying eggs. She crawled over clods, stubble, and plants, constantly feeling with the ovipositor the objects which she walked upon. On reaching a patch of soft earth she stopped and carefully worked the abdomen into the soil until the wings were flat on the ground. After remaining quiet for a short time she moved and repeated her actions in another spot. Three ovipositions were made in 15 minutes, and after each one the dirt was stirred as the abdomen was withdrawn and the hole left covered with dirt. The dirt around these holes was carefully removed with a teaspoon and eggs were found in clusters of 3 or 4 about ¼ inch below the surface of the ground. A total of 11 eggs were recovered from the three ovipositions.

Porosagrotis orthogonia moths were seen laying eggs in the open at Willow Creek on September 5, 1920. Just before dark moths were seen flying over a freshly worked, summer-fallowed field, being most abundant on the higher knolls and along the ridges where the soil was soft and loose. One moth was followed for some distance. She would fly a few feet, never getting over 10 inches above the ground, and would then crawl a short distance, continuously feeling the surface with her ovipositor. On reaching soft dirt she stopped and laid eggs for six minutes, going through the same actions as the moth observed in the cage. When she left the ground she flew straight away for at least ¼ mile at a height of 20 to 30 feet above the ground and was finally lost to view. Five eggs were recovered from this oviposition. Other moths were seen flying to the ridges and knolls, but it was too dark for further observations on this date. A few days later another moth was observed laying eggs on a knoll in the same field. One oviposition was made which lasted 23 minutes, during which time the moth was not in the least disturbed by any movements of the observer. When the ovipositor was finally withdrawn the moth swung around ¼ inch and started in again, this time remaining quiet for 17 minutes, after which she crawled under a clod to hide. This moth had oviposited for 40 minutes, and 12 eggs were recovered from the two holes. Moths were seen ovipositing along the knolls and ridges in this field for several days.

Moths in egg-laying show their preference for spots in the field where the soil is softest and also indicate a preference for freshly worked fields over those which have become caked and hard. Across the road from the freshly worked, summer-fallowed fields in which egg laying was observed was another summer-fallowed field which was spotted with Russian thistles and in which the soil was caked on the surface, due to a rain some two weeks earlier. Moths were continually observed flying into this field, but they usually flew on across it to the knolls in the freshly worked field, even though it was ¼ mile farther. Very few moths flew to similar knolls in the caked field, and those that alighted hid under the thistles or clods of dirt and made no attempt to lay eggs. Further evidence of this preference for mellow fields will be brought out later in this paper.

ATTRACTION OF THE MOTHS TO LIGHTS

Our first experiments in attracting the moths to lights were conducted at Wilsall on the evening of August 26, 1919. A large Coleman gas lamp was placed on the ground in the field where the grain had been destroyed the previous spring. As soon as it grew dark *Porosagrotis orthogonia* moths began to come to the light at the rate of one every two or three minutes. The lamp was placed upon bare sandy soil and the ground was well lighted for several feet on all sides. The moths usually struck the

ground from 2 to 15 feet from the light and then crawled toward it, where they could be easily picked up. As soon as it became totally dark the moths came to the light so rapidly that two men could not keep them picked up, and from 9 o'clock until midnight 282 females and 164 males of *P. orthogonia* were placed in rearing cans or killing bottles. This by no means represented the total number that came to the light, for hundreds escaped. Many different species of noctuids were attracted to the light, but fully 95 per cent were *P. orthogonia*. Ten of the females thus captured averaged 132 eggs. (Table II.)

In another part of the same field a Duro moth trap was run throughout the nights of August 26 and 27, 1919, and each morning the pan was well filled with *Porosagrotis orthogonia* moths. During the two nights 4,900 moths were caught, of which 4,200 were males. It is difficult to understand the preponderance of females caught at the larger light between 9 and 12 p. m. and the very small percentage of females caught at the smaller light during the entire night.

Experiments with trap lights were conducted on a somewhat larger scale at Willow Creek. A trap was designed which was made up of utensils commonly found on every farm and which would serve other purposes when not in use as a trap light (Pl. 30, B). It consists of a No. 2 galvanized-iron washtub and a No. 2 barn lantern. In addition, a galvanized-iron arch is made which fits across the tub and serves the dual purpose of deflecting the moths and holding the lantern. When the arch is wired firmly and the lantern swung in place the flame of the lantern is just above the edge of the tub. When set in place, the tub is staked down to prevent its being blown over, and about 4 inches of water are poured into it. About ⅛ to ¼ inch of kerosene is floated on the water to kill the moths which fall into it.

Eleven such traps were put out at Willow Creek, and observations were made during the flight period of *Porosagrotis orthogonia*. Two traps for catching moths alive were also used, and when these showed that *P. orthogonia* was beginning to fly the tub traps were put out on fields that had been heavily infested with worms.

During the first few nights the catches were small and the moths were counted. The numbers increased nightly until the height of flight, which was from August 19 to 24, inclusive. The night flight gradually decreased after the latter date. When the numbers became too large to count they were estimated, and during the height of flight they were measured in pints. As a pint measure holds from 962 to 1,000 moths, the measuring of moths gave a fairly accurate count. During the heavy flight several of the traps ran as high as 4,000 moths in a single night. The entire season's catch of *Porosagrotis orthogonia* moths in the 11 traps was 82,488. The catch on individual nights is shown in Table V.

TABLE V.—*Number of Porosagrotis orthogonia moths caught at trap lights at Willow Creek, Mont., during the season of 1920*

Date.	Weather conditions and remarks.	Number of moths caught.
Aug. 12	Rain in afternoon; night warm, cooler toward midnight	127
13	Early part of night warmer than usual; warm after midnight	342
14	Warm all night	1,528
15	Night moderately warm	1,566
16	Cooler, especially so after 9.30 p. m.; not as many moths flying	449
17	High wind in afternoon blew over traps; cold and windy after dark; no moths out	.....
18	Windy; cold soon after dark, almost frost; moths flew only a few minutes	68
19	Warm at 8 p. m.; moths flying heavily; windy and cooler after 11.30; fewer moths out	11,720
20	Warm west wind most of night; heavy flight of moths	13,990
21	Same as night before; height of flight 9.15 p. m	14,950
22	Warm, light west wind	13,650
23	Warm, west wind; wind strong and cold after 12.30 a. m	16,250
24	Cold and cloudy after 9 p. m.; southwest wind	7,490
25	Windy and cold; moonlight; no moths flying	.....
26	Windy until 8 p. m.; clear, cold; full moon; no moths flying	.....
27	Wind and heavy rain; cold; no moths	.....
28	Rain all morning; cold, windy night; traps not lighted	.....
29	Cool; little wind; few moths flying early; too cold after 9 p.m.	68
30	Clear, cool; bright moon; no moths flying	.....
31	Cloudy to 9.30; clear, cold; bright moon	119
Sept. 1	Moths flying in daylight after noon; few flying after dark	171
2	No moths flying after dark; a few found feeding	.....
3	Few moths out after dark; not attracted to lights	.....
4	Three *Noctua c-nigrum* caught; no others flying to light	.....
5	No moths flying to traps; traps taken up	.....
	Total	82,488

In all observations made at Willow Creek no moth was ever seen to land on the ground on its way to a light trap as did the moths at Wilsall the previous year. This may have been due to the fact that the tub hid the light so it would not strike the ground, and in order to keep in the path of light the moth had to fly straight to the trap. This was usually the case, and for the most part moths flying to the traps came on a straight line from 4 to 15 feet above the ground. They either struck the arch or lantern or went straight on over the trap.

On a still, dark, fairly warm night the moths would come to the traps in varying waves of abundance for which there was no apparent reason. There would be a cloud of moths for a few minutes and then they would come in scattering two's or three's. If the wind was strong no moths were caught in the traps and no moths could be found moving about on the ground. No moths were caught during a rain or ever after a rain, as long as the ground and vegetation remained wet. When the moon was bright, moths were not caught nor were any seen flying, though they would start the minute the moon went behind a cloud. Practically no moths were caught after the temperature had dropped below 58° F.

MOTHS BOTH NOCTURNAL AND DIURNAL

During the last half of August when the nights were warm and night flying was at its height the moths remained inactive during the day, hiding under clods and weeds. As the nights grew colder, the moths flew only an hour or two after dark, and on September 1 they were seen flying during the day. On this date they began flying about 4.30 p. m. and were seen in abundance feeding upon sunflowers, golden rod, tumbling mustard, yellow greasewood and lamb's quarter. All but one of the moths seen at flowers at this time were males, a search under weeds and clods at the same time revealing only females. At 8 p. m. when the flower patches were visited moths were still feeding in large numbers, practically all of them being females. They paid no attention to lights, and none were caught in a trap light set close by. As the night grew colder all of the moths disappeared and could be found hiding under clods or weeds. On the following day moths were found feeding at flowers at 1 p. m., and at 3.30 p. m. a patch of yellow greasewood (*Chrysanthus frigidus*), which seemed to be the favorite flower, had attracted dozens of *Porosagrotis orthogonia*, nearly all of which were males. At 5.30 p. m. the patch was again visited, and it was found that the males were then leaving and that females were flying to the flowers from a nearby summer-fallowed field. On September 3 moths of various species were found feeding during the morning, and at noon the flowers of the yellow greasewood were covered with moths, none of which were *P. orthogonia*. At 3 p. m. about 10 per cent of the moths present at flowers were *P. orthogonia*. These gradually increased in numbers until 6.15 p. m., at which time practically all other species had disappeared. After the moths had finished feeding they invariably flew toward the higher ridges and knolls in neighboring cultivated fields. Many of the moths in coming to the flowers were seen to fly from 200 to 500 yards directly against a stiff breeze. Moths were seen flying to flowers in large numbers until September 8, when a cold rain and wind occurred. The males were always found feeding earlier in the day and the females later, although neither was ever found before noon.

ECONOMIC IMPORTANCE

The record of this cutworm during the last 10 years has demonstrated its capacity for doing enormous damage to grain crops. When in 1911 *Porosagrotis orthogonia*, then an obscure insect, suddenly increased in numbers and did considerable damage to grain in southern Alberta (*10, p. 177*) little importance was attached to it. In the following year, however, when 33 per cent of all the grain sown in the Lethbridge land district was destroyed and an accurate estimate by the superintendent of the experiment station at Lethbridge placed the actual loss from this insect at from 30,000 to 35,000 acres (*11, p. 506*) it was looked upon as a pest of

major importance. During the last two years *P. orthogonia* has been responsible for losses in central Canada amounting to several million dollars.

In Montana the pale western cutworm has been on the increase since it was first noticed in 1915 and is now the most destructive insect pest with which the grain grower has to contend. In 1915 at Conrad 80 acres of wheat were destroyed and were reseeded to oats, which was also taken. Flax was then seeded, but this also was so badly injured that the owner plowed the field and summer fallowed it. This instance was typical of scores of losses in the district now composed of the counties of Chouteau, Teton, and Pondera.

During the next two years, especially in 1917, great losses were sustained throughout the north central portion of the State, due to cutworms which worked entirely beneath the surface of the soil and which were doubtless no other than *Porosagrotis orthogonia*. In 1919 the pale western cutworm appeared in destructive numbers farther south and caused severe losses in Park and Jefferson Counties as well as in the previously infested area. A conservative estimate of the losses for the year based on the reports of county agents, hundreds of questionnaires returned by farmers, and the personal investigation of many fields in different parts of the State, is at least 200,000 acres. In 1920 the injury in Jefferson and Park Counties was more widely extended, and there was a decided increase in the damage done in many of the districts previously infested. The loss over the entire State for the year is placed at 250,000 acres, valued at $3,000,000. In the Willow Creek district in Jefferson County a careful survey conducted in 1920 showed that 29 per cent of the total seeded area had been destroyed by this cutworm, and a similar survey in several of the northern counties showed a loss of 35 per cent of the grain crops planted.

To show perhaps a little more clearly what this cutworm has been doing it may be stated that 100 fields personally inspected during the summer showed a loss of 2,437 acres out of a total of 6,844 in 1919, and in 1920 a loss of 3,382 acres out of 6,844, or 35.7 per cent in 1919 and 49.4 per cent in 1920. Mr. George O. Sanford, manager of the Sun River irrigation project, has stated to us that of the 15,300 acres seeded to crop on the Greenfield Bench in 1920, 7,345 acres was a total loss and that some damage was done to the remainder. Using the figures he has given for the average yields on the undestroyed acreage—wheat 11.5 bushels, oats 20.86 bushels, and flax 6.31 bushels—the average value of the principal farm crops of that section was at least $15 per acre. Accordingly, using that as a fair valuation per acre of the crops destroyed, the pale western cutworm inflicted a loss of $110,175 in this one comparatively small territory. Although these losses took place on irrigable land, no water was available until after the first of June. Were it not that irrigation made it possible in some cases to reseed and grow a late crop on part of the originally destroyed area, the loss would have been 55 per cent instead of 48 per cent of the acreage in that district.

EXPERIMENTS IN CONTROL

ORDINARY CUTWORM CONTROL METHODS NOT EFFECTIVE

Early in our study of *Porosagrotis orthogonia* it became apparent that the ordinary method of scattering poisoned bran mash over an infested field was not effective in controlling this species. On May 2, 1919, poisoned bran mash was scattered over a heavily infested field in southern Montana at the rate of 20 pounds to the acre and was followed by three other applications on successive days. The field was examined each day by the owner, who reported that he could not find a single dead worm. On May 7 the treated area was carefully examined by one of the writers but no dead worms could be found, nor could any decrease in the number of live worms be noted. On May 7, 1919, poisoned bran mash was scattered over 2 acres of heavily infested wheat in northern Montana. During the next 10 days no results whatever were secured from this treatment. County agents and numerous farmers have reported that attempts to poison this species by the ordinary method of scattering poisoned bran mash over the surface have always resulted in failure.

At Willow Creek in 1920 pale western cutworms were noticed crawling over the surface of the ground in the evening after a rain, and an attempt was made to kill them by scattering poisoned bran mash during the night. The bait was scattered soon after dark over an area which included bare ground, scattering wheat, and a good stand of wheat, all heavily infested. Observations were made during the night by the aid of automobile headlights, and many of the worms were seen feeding upon the bait. Two days later a search was made for dead cutworms. In the area where there was no vegetation it was estimated that 60 per cent of the worms were killed; where there was a scattering of wheat the percentage of dead worms was 50; and where there was a good stand of wheat 43 per cent were killed. It is possible that several night applications of poisoned bran mash during rainy weather might bring about a satisfactory control, but as yet we have not had the opportunity to try it.

POISONED BRAN MASH HARROWED INTO THE SOIL

Strickland reports (17) that poisoned bran mash harrowed into the soil gave gratifying results. This method was tried out at Wilsall in May, 1919. Poisoned bran mash was scattered over ½ acre of heavily infested wheat at the rate of 25 pounds to the acre. On several square rods where the worms were thickest the mash was worked well into the soil with a hand rake, and the remainder of the treated area was thoroughly worked with a spike-toothed harrow. The plot was carefully examined three days after the poisoned bran mash was applied, and it was estimated that the treatment was not more than 1 per cent effective. Very few dead cutworms could be found, and eventually all of the wheat was destroyed.

POISONED BRAN MASH DRILLED INTO THE SOIL

Since *Porosagrotis orthogonia* very rarely comes to the surface to feed, placing the poisoned bran mash beneath the soil was tried in the hope that the cutworms would thus come in contact with it and feed upon it. The most promising way of doing this seemed to be with a seed drill. This method was tried out in northern Montana at Havre and in southern Montana at Wilsall.

TESTS AT HAVRE

At Havre two formulæ were used.

FORMULA NO. 1

Shorts	pounds	25
Paris green	do	1
Oranges		4
Molasses	quarts	2
Water	gallon	1

FORMULA NO. 2

Shorts	pounds	25
Paris green	do	1
Molasses	gallon	1
Water	quarts	2

These mixtures after being prepared were spread out and allowed to dry for 24 hours. When dry, No. 2 was distinctly stronger smelling, although both had a good molasses odor. The reason for using the large amount of molasses in these formulae was to secure a distinct odor in the dried material which we hoped might attract cutworms in the soil for some little distance.

The dried material was seeded into the ground with a Van Brunt drill at the rate of 16 pounds to the acre and at a depth of about 1.5 inches. Six acres were treated. The drill was run at right angles to the rows of grain so that the worms in working from plant to plant would only move a few inches before coming in contact with the bran. The greatest difficulty encountered was in getting the bran to feed evenly through the drill. When it was sufficiently dry to be well divided it was too light to force its way through and it was necessary to agitate the mixture continuously in the seeder box to get anywhere near an even distribution.

The field was examined two days after the poisoned bran mash was drilled in, and it was found that formula No. 1 had killed approximately 50 per cent of the worms while formula No. 2 gave slightly better results with a kill of about 55 per cent, which was not enough to prevent the destruction of the crop.

TESTS AT WILSALL

On June 8, 1919, a similar test was conducted at Wilsall. The following formula was used:

Shorts	pounds	25
Paris green	do	½
Salt	do	½
Molasses	quarts	2
Water	gallon	1

After mixing, the mash was spread out to dry, which with a hot sun and a fair breeze was accomplished in half a day. The mixture was distributed over 25 acres of infested wheat at the rate of 12 pounds of the dry mash to the acre. Sixteen acres were sown with all the spouts of the drill working and 9 acres with every other one closed. The drill was run across the old grain rows. The greatest difficulty encountered was the same as in the test at Havre—the mixture was too light to feed evenly through the drill. This was overcome by using two men on the drill, one to drive and one to keep the bran shaken down where it would come in contact with the disks of the drill. This was done by frequently pounding the seeder box with a padded hammer and punching out packed masses with a small stick. Dead and dying worms were found the second day after the poisoned bran was drilled in, and on the third day a careful examination was made and it was estimated that from 50 to 60 per cent of the worms had been killed. The field was examined two weeks later, and there was a very noticeable difference in the number of worms found in the treated and untreated areas, but this did not prevent total destruction of the crop.

TEST AT WILLOW CREEK

During May, 1920, poisoned bran mash was distributed with a grain drill over a very badly infested field at Willow Creek. Cutworms were uniformly scattered over a 40-acre field of spring wheat, and at the time the poisoned bran mash was applied had destroyed about half the plants. Conditions were ideal for a good test of control methods. The following mixtures were used:

FORMULA NO. 1

Shorts	pounds	25
Paris green	do	1
Molasses	quarts	2
Salt	pound	1
Water	gallon	1

After mixing, this was thoroughly dried out and was then seeded 2 inches deep through a Van Brunt drill at the rate of 20 pounds to the acre. Two acres were sown. This mixture did not feed uniformly through the drill unless constantly agitated.

FORMULA NO. 2

Shorts	pounds	25
White arsenic	do	1½
Molasses	quarts	2
Salt	pound	1

This was prepared and distributed in the same manner as formula No. 1. Two acres were sown.

FORMULA NO. 3

Shorts	pounds	25
Paris green	do	1
Salt	do	1

This was mixed dry and seeded at the rate of 12½ pounds to the acre. It ran through the drill about the same as the mixtures which were mixed wet and then dried. Two acres were sown.

FORMULA NO. 4

Shorts	pounds	25
White arsenic	do	1½
Salt	do	1

This was prepared dry and then thoroughly mixed with an equal bulk of wheat. This combination ran through the drill very evenly, the wheat being heavy enough to carry the bran through the drill without clogging. Two acres were seeded at the rate of 12½ pounds of bran to the acre. Three days after the poisoned bran was put out the field was examined and it was estimated that about 10 per cent of the worms in the treated areas had been killed. No difference could be seen in the effectiveness of the various formulæ, and numerous living cutworms remained in all the plots. One week later the plots were again examined and the number of dead cutworms had not materially increased. A final examination of the field was made on June 14, three weeks after the poisoned bran was put out. Cutworms were found in abundance on all plots, and in plots 1, 2, and 3 practically every spear of wheat had disappeared. In plot 4, which was seeded with a mixture of wheat and poisoned bran, the wheat was about 3 inches in height and was being rapidly cut off, 50 per cent of the new stand being already destroyed. From a practical standpoint the control on all plots was a complete failure and an absolute waste of materials.

POISONED BAIT SPRAY FOR ADULTS

The presence of large numbers of *Porosagrotis orthogonia* moths at flowers led us to try out the following poisoned bait spray:

Water	gallon	1
Molasses	pint	½
White arsenic	ounce	½
Amyl acetate	do	½

This was scattered in coarse droplets over flowers and vegetation where moths were abundant. Many flies and bees were killed, but no moths were observed feeding upon the bait, and dead moths were never found in the vicinity of the sprayed vegetation.

CULTURAL METHODS AS A MEANS OF CONTROL.

In our study of *Porosagrotis orthogonia* under field conditions we have repeatedly noticed instances where crops in one field were completely destroyed, while in an adjacent field the grain escaped unharmed. This suggested that the manner in which the ground was worked before the crop was put in might have been responsible for the great difference in the amount of damage done in the two fields, and in 1920 a survey was conducted with the object of determining the relation of cultural methods to cutworm abundance. This survey was conducted in two ways: (1) By an auto trip through the districts most heavily infested by means of which hundreds of farmers were personally interviewed and the histories of their fields obtained for the period 1919–20; (2) by questionnaires sent to all farm bureau members in counties where *Porosagrotis orthogonia* was known to be present.

The percentage of cutworm losses under various cultural methods as shown by a study of fields, the owners of which were personally interviewed, is shown in Table VI.

TABLE VI.—*Percentage of Porosagrotis orthogonia injury in 1920 under various methods of cultivation in preparation for seeding*

Cultivation between previous crop and 1920 crop.	Number of fields.	Total acres.	Acres lost.	Percentage lost.
Fall double disked	8	465	200	43.0
Spring double disked	39	2,250	1,301	57.0
Spring single disked	36	1,536	661	43.0
Fall-plowed; disked or harrowed before seeding	13	643	138	21.0
Spring-plowed disked or harrowed before seeding	51	2,465	666	27.0
Spring-harrowed	18	1,332	526	40.0
Summer-fallowed	39	3,114	267	8.5

A study of the results shows a high percentage of cutworm injury in all cases where the stubble was only disked or harrowed before seeding. Fields which were plowed either in the fall or spring showed a somewhat lower percentage, while summer-fallowed fields showed only the very small loss of 8.5 per cent.

While the average cutworm loss in summer-fallowed fields was low, yet several individual fields suffered severe losses. It was therefore decided to make a study of the histories of summer-fallowed fields during the two seasons of 1919 and 1920. Since the moths were known to

prefer loose mellow soil for egg-laying, it was thought that the condition of the ground in summer-fallowed fields during the egg-laying period might have considerable influence on the number of eggs deposited in the field and on the percentage of loss the following spring. Since egg laying does not begin until about August 15, fields which are not cultivated or disturbed in any way after July 15 become more or less crusted and caked. Fields which are cultivated in any way during the last part of July or during August, on the other hand, are very likely to be soft and mellow during the egg-laying period, thus offering the very conditions which the moths are seeking. Forty-eight fields, for which we had data for both 1919 and 1920, were therefore classified as crusted, if they were worked only before July 15, or as mellow, if they had been worked after that date. The percentage of loss for the variously worked fields is shown in Table VII.

TABLE VII.—*Percentage of Porosagrotis orthogonia injury during 1919 and 1920 in "crusted" and "mellow" summer-fallowed fields. Data secured by personal interview with grower*

Condition of field and time of cultivation.	Number of fields.	Total acres.	Number of fields infested.	Acres lost.	Percentage lost.
"Crusted"—worked only before July 15	27	1,828	3	14	00.7
"Mellow"—worked after July 15	21	1,562	14	425	27.2

Farmers were asked in questionnaires sent to farm bureau members in counties infested with *Porosagrotis orthogonia* whether they had noticed any relation between the condition of the soil in summer-fallowed fields during August and the amount of pale western cutworm injury the following spring. Sixty-eight grain growers answered this question. Fifty-three said that injury was most severe in fields where the surface soil was well pulverized, or, as one farmer stated it, "The more mulch the more worms." Seven reported that the greatest injury had occurred in fields that had been crusted during August, and five stated that they could see no relation between soil conditions and cutworm injury.

The foregoing data, together with the fact that we have seen ovipositing females show a distinct preference for mellow fields, leads us to the conclusion that the physical condition of the soil during the egg-laying period has a very important bearing upon the amount of *Porosagrotis orthogonia* injury that may occur the following spring. According to the data at hand greatest injury may be expected in fields in which the surface soil is loose and well pulverized during the egg-laying period. This loose, mellow condition may have been brought about in summer-fallowed fields by tillage during late July and August or it may

be a natural condition such as is found on knolls and ridges where the soil is generally light and easily drifted. In fields where a crop is removed during July or August the surface crust may become broken and pulverized in numerous places by the disturbance of the soil in connection with harvesting, thus offering the moths many desirable spots for egg laying. Injury may be least expected to occur in fields in which the surface soil is hard or crusted during the egg-laying period. In most instances this condition can be brought about by not disturbing the ground in any way between July 15 and September 15. If farmers in preparing their grain fields for seeding will be governed by these principles it is believed that *Porosagrotis orthogonia* injury can be greatly reduced. Fortunately this method of handling summer-fallowed fields does not interfere with approved farm practices, and in fact agrees very closely with the recommendations of the agronomists.

NATURAL ENEMIES

Unlike most of our common cutworms, *Porosagrotis orthogonia* suffers comparatively little from attack by natural enemies. Much difficulty has been encountered in rearing various other species taken in the field as larvæ, particularly the army cutworm, *Chorizagrotis auxiliaris*, on account of the high percentage that developed disease or parasites. This has not been the case with the present species. Our records for 1915 show that out of a large number of army cutworms reared individually only 35 per cent were brought through to the moth stage, parasites emerged from 24 per cent, 21 per cent died of disease, and the remaining 20 per cent died in the pupa stage, mostly on account of insect parasites. In 1919, 55 per cent of *P. orthogonia* larvæ handled in the same way were reared to adults. Of the 45 per cent that died, very few seemed to die of any disease, and parasites emerged from only two larvæ.

In 1920, out of 960 *Porosagrotis orthogonia* larvæ collected in the field, 13.7 per cent were parasitized, 12.2 per cent by Diptera and 1.5 per cent by Hymenoptera. The parasites which emerged were 14 *Bonnetia compta* Fall and 1 *Peleteria robusta* Wied.

The common wild birds of the prairie are the most beneficial natural check that we have observed. The western grasshopper sparrow, *Ammodramus savannarum bimaculatus* Swainson, particularly, has been watched while digging out the larvæ and carrying them away to its young. In many parts of the cutworm-infested regions it has been a common sight toward the last of June to see thousands of small excavations made by the western grasshopper sparrow, horned larks *Otocoris alpestris leucolaema* Coues (Pl. 30, C), and possibly other wild birds in their search for the larvæ.

Although the common ground squirrel, *Citellus richardsoni* Sabine, has at times been known to seek out and devour large numbers of cutworm

larvæ, we do not believe that ground squirrels are of much importance as a natural check.

In some instances both larvae and adults of *Calosoma tepidum* Lec. have been observed to be especially numerous about cutworm-infested fields and are, we believe, one of the lesser important predators.

DESCRIPTION OF STAGES

EGG

Spheroidal, flattened dorso-ventrally, glistening milk-white when first laid (Pl. C, 1), later becoming dull gray: 1 mm. in diameter, 8 mm. in height. Around the micropyle is the usual rosette which lies in the center of a finely reticulated area about 0.3 mm. in diameter. The pattern of the reticulation is shown in figure 1. From the edge of the reticulated area about 30 slightly raised longitudinal ribs radiate toward the base, extending approximately four-fifths the distance from the apex to the base. The ribs are sometimes irregularly branched or connected by cross ridges. The shallow channels between the ribs are transversely striated and lightly pitted. The chorion on the basal fifth of the egg is smooth and glistening without ridges or definite reticulation.

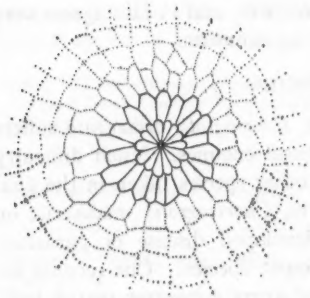

FIG. 1.—*Porosagrotis orthogonia:* reticulation about the micropyle. Highly magnified.

LARVA [1]

FIRST INSTAR

Head width, 0.4 to 0.43 mm.; average 0.41 mm.

Total length of body, 2.4 to 3 mm.; average 2.8 mm.

The head (Pl. 28, A) is a very dark glistening brown, almost black; clypeus and front same color as epicranium; adfrontals indistinct, but apparently extending almost to deep indentations at summit; mandibles, labrum, ring-shaped sclerite resting on mentum, and cardo dark brown; submentum, margins of stipes next the mentum, the antennae, and labial palpae brownish; ocellar region blackish.

The posterior portion of the thoracic shield dark brown; anterior margin very light brown. The thoracic legs are brownish with dark brown transverse lines immediately anterior and partially surrounding coxæ.

[1] In the description of the larva the naming of the various parts follows very largely the system of William T. M. Forbes (4).

Prolegs on segments 9, 10, and 13 (counting the head as the first segment); crotchets brown; rudimentary prolegs slightly visible as small tubercles on segment 8.

There is a reddish brown mottling over the lateral and dorsal regions, becoming more distinct along the posterior segments. Before the larva has taken food this coloration appears much darker. The general color of the newly hatched larva is brown. The spiracles dark brown, setæ single and arising from minute brownish tubercles.

SECOND INSTAR

Head width, 0.47 to 0.576 mm.; average 0.53 mm.

Total length of body, 2.8 to 3.77 mm.; average 3.3 mm.

The head (Pl. 28, B) remains a dark, shiny brown; mandibles and labrum dark brown, mandibles at teeth and labrum at notch blackish; ring-shaped sclerite resting on mentum blackened ventrally and with its setæ within the sclerite; cardo dark brown; submentum, margins of stipes next the mentum, antennæ, and labial palpæ brownish; ocellar region blackish.

Thoracic shield dark brown posteriorly, but not as dark as head; anterior margin light brown. On each side of the light brown dorsal stripe is a dark spot on the anterior portion of the shield with several dark spots laterad.

Prolegs on segments 8, 9, 10, and 13; crotchets on eighth segment consisting of only two or three hooks; rudimentary prolegs on segment 7 beginning to show; crotchets reddish brown.

The dorsal stripe is gray, bordered with broken lines of brown; subdorsal and lateral stripes brownish; spiracles dark brown; setæ single, tubercles brownish.

THIRD INSTAR

Head width, 0.68 to 0.786 mm.; average 0.75 mm.

Total length of body, 4.19 to 5.5 mm.; average 4.29 mm.

Head brown (Pl. 28, C) with upper parts of lobes of epicranium dark brown; front brown but with its lower margin together with clypeus dark brown; mandibles reddish brown to black at teeth; labrum dark brown with blackened notch, ring-shaped sclerite resting on mentum blackened ventrally and with its setæ within sclerite; cardo dark brown; submentum, margins of stipes next the mentum, antennæ and labial palpæ brownish; ocellar region blackish.

Thoracic shield dark brown, almost black at posterior region; anteriorly it is a lighter brownish gray with a small black spot on either side of the light dorsal stripe and with several dark spots laterad.

Thoracic legs tinged with brown, claws and markings anterior to and partially surrounding basal joints reddish brown.

The dorsal stripe along the body is made of broken gray which is bordered irregularly with brown. Subdorsal and lateral stripes brownish; general color same as dorsal stripe, or lighter, with a greenish tinge. Spiracles dark brown; setæ single, tubercles greenish brown.

FOURTH INSTAR

Head width, 0.84 to 1.14 mm.; average 1.02 mm.

Total length of body, 6.5 to 12.5 mm.; average 8.9 mm.

Coloration of head slightly modified from preceding instar; front not as dark, clypeus a lighter brown, and cranial lobes considerably darker at top (Pl. 28, D); mandibles are black at teeth and fade to reddish brown to dark brown near articulations; labrum dark brown with blackened notch; ring-shaped sclerite resting on mentum blackened ventrally and with its setæ within the sclerite; cardo dark brown; submentum, margins of stipes next the mentum, antennæ and labial palpæ brownish; ocellar region blackish.

Posterior part of thoracic shield dark brown; anteriorly it is lighter, and in this lighter area are three distinct dark spots on either side of the dorsal line and also larger dark spots toward the lateral ends of the shield.

Thoracic legs tinged with brown, claws and markings anterior to and partially surrounding basal joints, reddish brown.

Prolegs on segments 8, 9, 10, and 13 and rudimentary prolegs on segment 7; crotchets reddish brown.

The dorsal line is a greenish gray partially broken and bordered with brown; subdorsal and lateral lines brownish; general color green to gray; spiracles dark brown; tubercles are greenish, setæ single and ringed at base with a light color.

FIFTH INSTAR

Head width, 1.38 mm. to 1.98 mm.; average 1.83 mm.

Total length of body, 11.5 mm. to 18.0 mm.; average 16.1 mm.

General color of head much lighter (Pl. 28, E); ocellar region very dark brown; ocelli 1, 2, and 6 colorless, other three dark; mandibles reddish brown to black at teeth; lower margin of labrum reddish, blackened at notch; cardo and submentum brown with the margins of stipes next the mentum same color and with the stripe becoming wider about the base of the palpifer; sclerite resting on mentum blackened.

The two bands of dark brown on the epicranium and bordering the adfrontals become prominent for the first time in this instar (Pl. C, 2). The rest of the head seems to have lost color, leaving these two stripes which run from points even with the base of the clypeus to the second epicranial setæ, above which they gradually fade out about the first epicranial setæ.

The thoracic shield is brownish with a light dorsal stripe; in the lighter area on the anterior margin of the shield and on either side of the dorsal stripe are distinct blackened spots, with other dark spots toward the lateral margins of the shield.

Thoracic legs tinged with brown, claws and markings anterior to and partially surrounding basal joints reddish brown.

Fully developed prolegs on segments 7, 8, 9, 10, and 13 are concolorous with body; crotchets brownish. The anal plate is marked with a transverse row of small brownish spots anterior to the setæ.

The dorsal line is a greenish gray and bordered with brown; the subdorsal and lateral stripes brownish; the general color is about the same or perhaps a trifle lighter than the dorsal stripe.

SIXTH INSTAR

Head width, 1.98 to 2.64 mm.; average 2.41 mm.

Total length of body, 2.0 to 2.5 cm.; average 2.2 cm.

Head light brown; ocellar region very dark brown; ocelli 1, 2, and 6 transparent, other three brownish; mandibles reddish brown to black at teeth; lower margin of labrum reddish, blackened at notch; cardo and submentum brown with the margins of stipes next the mentum same color with the stripe broadening apically about the base of the palpifer.

The two conspicuous bands of dark brown persist on the epicranium bordering the adfrontals (Pl. 28, F); the stripes become a lighter color at top, ending near the first epicranial setæ; a denser colored portion of each band follows the adfrontals almost to their apex.

The thoracic shield is brownish with a light dorsal stripe; in the lighter area on the anterior margin of the shield and on either side of the dorsal stripe are distinct blackened spots with other dark spots toward the lateral margins of the shield.

The thoracic legs tinged with brown, claws and markings anterior to and partially surrounding basal joints reddish brown.

Fully developed prolegs are found on segments 7, 8, 9, 10, and 13, concolorous with body; crotchets brownish. The anal plate on the thirteenth segment, a pale green in color, possesses a transverse row of brownish spots anterior to the setæ; a light-colored dorsal stripe runs through the plate.

The dorsal stripe is a broken gray green bordered with light brown; the subdorsal is brownish, but the lateral has become lighter in color, brownish gray. Setæ single, ringed at base with a light-colored area; tubercles greenish brown; spiracles black.

SEVENTH INSTAR

Head width, 2.70 to 3.18 mm.; average 2.93 mm.

Total length of body, 2.9 to 3.2 cm.; average 3.02 cm.

Head light brown; ocellar region very dark brown, ocelli 1, 2, and 6 transparent, other three brownish; mandibles reddish brown to black at

teeth; lower margin of labrum reddish; ringed-shaped sclerite resting on mentum blackened; cardo and submentum brown with margins of stipes, next the mentum, same color with the stripe broadening about the base of the palpifer.

The bands of dark brown bordering the adfrontals have the same appearance as in the previous instar (Pl. 29, A).

The thoracic shield is dark brown with a distinct light-colored dorsal stripe on either side of which toward the anterior margin of the shield is a small blackened area with other dark spots toward the lateral margins of the shield.

The thoracic legs are tinged slightly with brown toward the apical joints; claws reddish brown, and color markings remain the same about the basal joints. Prolegs on segments 7, 8, 9, 10, and 13 are concolorous, crotchets brownish; the anal plate is a gray green with dark spots in a transverse row anterior to the setæ; a light-colored dorsal stripe runs through the plate.

The dorsal stripe is gray-green, and the brown borders in the previous instars appear greenish in this one; the subdorsal and lateral stripes are greenish with a slight tinge of brown; the general color is a greenish gray; setæ single and ringed at base with light area; spiracles black, tubercles green; the pulsating dorsal vessel can be easily seen through the epidermis.

EIGHTH INSTAR

Head width, 3.18 to 3.42 mm.; average 3.36 mm.

Total length of body, 3.1 to 3.6 cm.; average 3.34 cm.

The general color of the head is a light brown with a slight yellowish tinge; ocellar region dark brown, ocelli 1, 2, and 6 colorless, other three dark brown to black; the front is a trifle lighter in color than the clypeus; the adfrontals, which are made very distinct by a darker brown coloration following the frontal sutures and by the dark bands following the epicranial sutures, extend to the bottom of the deep indentation separating the epicranial lobes at the summit; the mandibles are black at teeth and at points of articulation, and between lies an area which is a very pale brown in color; submentum and cardo brown; chitinized brownish stripe on margin of stipes, next the mentum, broadened about base of palpifer; antennæ, labial and maxillary palpæ brownish.

The two bands of dark brown which border the adfrontals and which are very conspicuous in the fifth, sixth, and seventh instars, are somewhat reduced, especially the upper parts of the bands in the regions of the first and second setæ, in the advanced stage of the last instar (Pl. 29, B); during the first days of the instar the bands extend from points even with the base of the clypeus to the second epicranial setæ, running between the setæ and the adfrontals; here they become slightly less dense in color and divided, parts of the stripes continuing along the

adfrontals and the other, lighter but wider parts, extending back to the regions of the first epicranial setæ.

The thoracic shield is pale brown with a prominent whitish dorsal stripe; there are small spotted dark brown areas toward the lateral margins of the shield and several smaller brown spots on either side of the dorsal stripe.

The thoracic legs are tinged with brown, especially laterad; about the base of the coxæ and femora anteriorly are reddish brown stripes.

The prolegs on segments 7, 8, 9, 10, and 13 are concolorous with body and possess reddish brown crotchets.

In the first part of this instar (Pl. C, 3) there are distinct dorsal and subdorsal stripes, the dorsal appearing as dark green and produced by the pulsating dorsal vessel beneath the epidermis, and subdorsal as brownish; a broken whitish lateral stripe is quite distinct; in the advanced stage of the instar with the exception of the tubercles there are no markings on the body, which becomes a bleached out yellowish color.

The spiracles are black; setæ, which are a reddish brown especially in the head region, are single; tubercles a greenish brown but immediately about the base of each seta there is a ring of lighter color; the anal plate is marked by a transverse row of dark brown spots anterior to the setæ.

PUPA

Length 17.5 mm., width 5.7 mm.

Typical noctuid pupa; labial palpæ exposed for entire length; maxillæ, mesothoracic legs and antennæ of practically same length and extending almost to caudal margin of wings; prothoracic femora exposed; tips of metathoracic legs visible and mesothoracic legs not extending to eye pieces; dorsal cephalic margins of abdominal segments 5, 6, and 7 marked with many small chitinized circular pits which extend to ventral surfaces of segments but where they are fewer in number and less prominent. The slightly bifurcate, blackish, rough cremaster ends in two stout often incurved spines set far apart. The color of pupa varies from a light straw color to a dark brown, according to age (Pl. C, 4).

ADULT [1]

"*Agrotis orthogonia*" nov. sp.

All the tibiae spinose. Antennae of the male strongly serrate. Middle of the second joint of palpi black, its outer edge and tip, as well as the third joint, light. Head and thorax gray. Anterior wings dark gray; all the markings well expressed; half-line followed by a white shade line; basal space lighter than the other portions of the wing; interior line forming a very long outward projection below the submedian vein, and another shorter one on the costa, the line is white and distinct, bordered with black on each side, between the submedian and subcostal veins it is straight, except one lobe below the median vein, to which the concolorous, black edged claviform spot is attached; subcostal median and submedian veins white, and contrasting

[1] The description of the adult is quoted from Morrison (*15*).

(Pl. C, 5); orbicular spot elliptical, with an outer black ring, within which appears a white annulus, inclosing the gray center; reniform spot large and of the usual shape, the portion of its black annulus, beneath the median vein, separated and very distinct; exterior line rounded, formed of interspaced luniform marks, followed by a white shade line; subterminal space rather lighter than the median space, terminal space again dark; a series of partially effaced cuneiform marks, before the white subterminal line, which forms two short teeth on the second and third median branches. Posterior wings whitish at the base, with a black terminal band and contrasting white fringes. Beneath whitish, the center of the median space dark, and the neighborhood of the median vein, on the anterior wings, clothed with long soft hair.

Expanse, 34 mm.

Hab. Glencoe, Nebraska. Received from Mr. G. M. Dodge. (No.66).

The nearest ally of this fine species is the European *Agrotis vestigiales* Rott.

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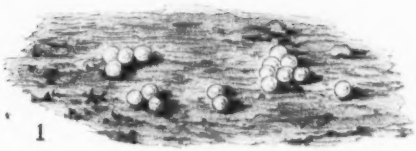
PLATE C

Porosagrotis orthogonia:

1.—Eggs.
2.—Cast head of fifth-instar larva.
3.—Eighth-instar larva.
4.—Pupa in earthen cell.
5.—Adult, male.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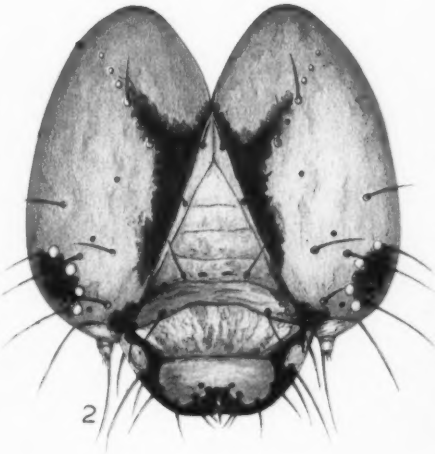
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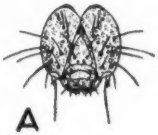
PLATE 28

Porosagrotis orthogonia:

A, B, C, D, E, F.—Cast heads of first- to sixth-instar larvæ.



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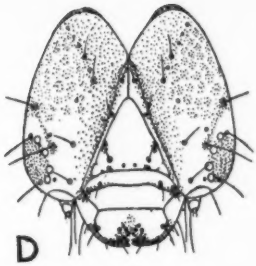

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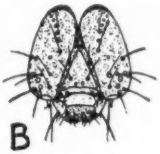

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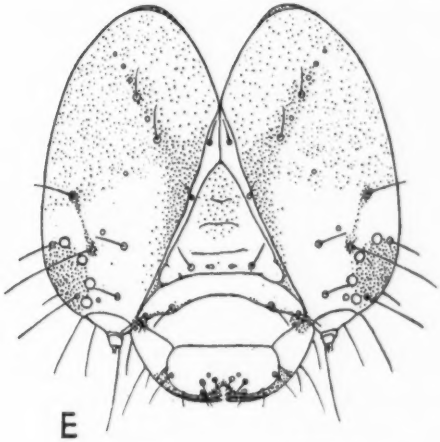

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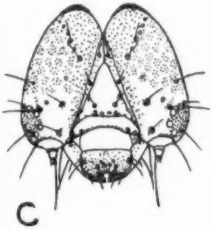

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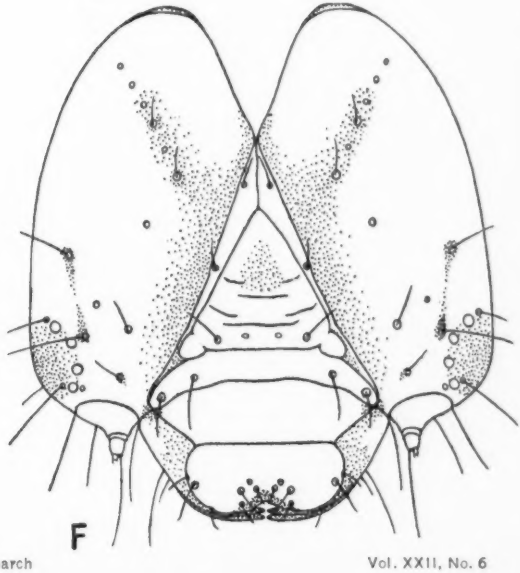

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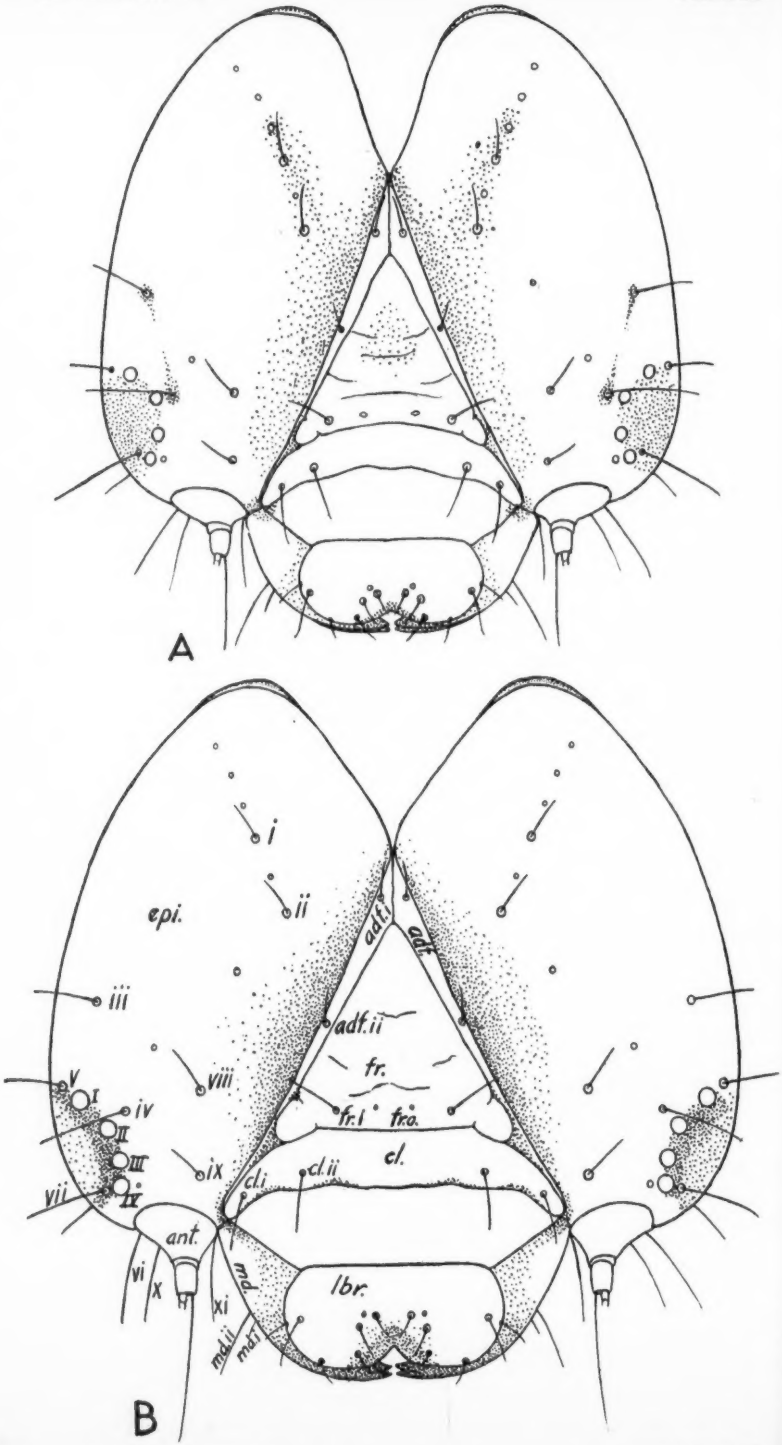
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PLATE 29

Porosagrotis orthogonia:

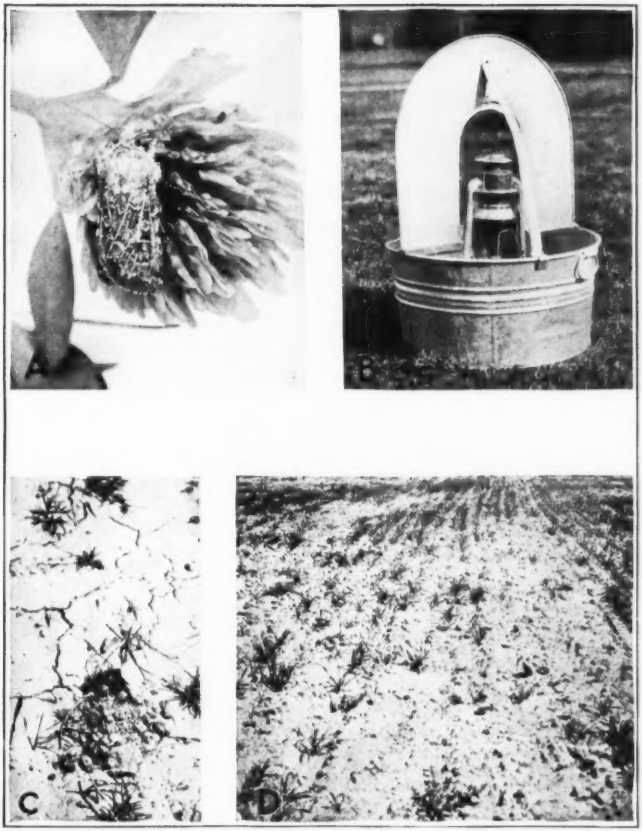
A.—Cast head of seventh-instar larva.

B.—Cast head of eighth-instar larva with setæ numbered. *Adf.*, adfrontal sclerite, *adf. i*, *adf. ii*, its setæ; *fr.*, frontal sclerite; *fr. i*, frontal setæ; *fr. o*, frontal puncture; *cl.*, clypeus; *cl. i*, *cl. ii*, its setæ; *lbr.*, labrum; *ant.*, antennæ; *md.*, mandible; *md. i*, *md. ii*, its setæ; *i* to *xi*, setæ of epicranium, *I* to *IV*, first four ocelli.

PLATE 30

Porosagrotis orthogonia:

A.—Moth feeding on clover blossom.
B.—Light trap.
C.—Excavation made by horned lark in digging out cutworm.
D.—Wheat field attacked by the larvæ.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BIOLOGY OF EMBAPHION MURICATUM

By J. S. WADE, *Scientific Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology;* systematic description of the larva by ADAM G. BÖVING, *Bureau of Entomology, United States Department of Agriculture*

INTRODUCTION

Considerable damage has been wrought during the past six or seven years by the larvæ of *Embaphion muricatum* Say and related species of false wireworms to growing wheat and other field crops throughout the semiarid and middle western United States. The area of greatest injury embraces approximately the western half of Nebraska, Kansas, and Oklahoma, and the eastern third of Colorado and New Mexico, although losses of varying magnitude have been reported in various localities over the greater part of all these States. In view of the obscure character of the injury, it seems quite probable that much crop damage commonly charged to other causes in reality has been brought about by this pest. The steady transformation in recent years of grassy prairies into cultivated fields has been an important factor, because the removal of native food plants causes this and related species to feed more and more upon cultivated grains. The hardiness of the insect and the rapidity of its adaptation to changed conditions and to new host plants indicate that this species is potentially a serious menace to grain production within the infested region.

EARLY RECORDS

The species under discussion was originally described in 1824 as *Akis muricata* by Thomas Say (*1*),[1] who stated that it—

> inhabits Arkansa at the Rocky Mountains

and that—

> as it does not entirely agree with any genus the characters of which Latreille has noted, it may be proper to remove it to the Blapsidae, under a separate genus, which may be named *Embaphion*.

This description was reprinted in 1859 in the LeConte edition of Say's (*1*) works, with a brief supplementary editorial note indicating relationship of the genus Embaphion to the genus Eleodes. A single specimen from Texas was described as *Eleodes contusum* by LeConte (*2*) in 1853, who stated that it—

> resembles *E. muricatum* Say but is longer and narrower with the broad margin of the elytra more suddenly reflexed and almost perpendicular. Although so different in form, this genus is only distinguished from *Eleodes* by the inferior plane of the

[1] Reference is made by number (italic) to "Literature cited," p. 334.

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mentum being more rounded and more deeply impressed; its anterior margin is slightly incised; the lateral angles are so much reflexed as to be invisible; the tarsi are sulcate beneath and fringed at the apex and sides with short spines; the middle joints of the posterior tarsi appear more elongated than in *Eleodes*. I have grave doubt of the generic value of any of these differences, and several nondescript species from New Mexico seem to be intermediate both by the form of the body and by the differences in the mentum.

The characters distinguishing *Embaphion contusum* from *Embaphion muricatum* were discussed by LeConte (*3*) in 1859. A brief résumé of the previous history of the genus was made by Lacordaire (*4, v. 5, p. 152; atlas, pl. 50, fig. 2*) in 1859, in which attention was called to Say's inadequate designation of the genus *Embaphion* and to variation of the species with its geographical distribution. Horn (*5, p. 320–322*) in 1870, in his discussion of the genus, indicated the feeble taxonomic characters which separate this genus from Eleodes. In referring to the species *Embaphion muricatum* he states:

> This species may be readily distinguished from the others of the genus by the very broad foliaceous margin of the thorax and elytra, very strongly reflexed. The elytral margin extends beyond the apex and the two meet on a line with the suture. The thoracic margin is broad and widens behind, so that the hind angles are prominent, sub-acute, and project backwards over the basal angles of the elytra. The thorax itself (less the margins) is narrow, longer than broad, and about equal to half the width of the elytra (without margin). The disc of elytra (without margin) is elongate oval, the humeral angles not prominent and are rounded. The angles formed by the margin are nearly right. The base of the thorax is strongly trisinuate; the base of the thorax proper being rounded, that of the margin on each side emarginate. The base of elytra is emarginate at middle, and on each side broadly rounded.

He stated further that *Embaphion concavum*, described by LeConte (*2*) in 1853, is

> merely a large form with more strongly reflexed margins. The elytra of both forms are sculptured with approximate series of fine punctures, each bearing a short hair.

Blaisdell's (*11, p. 473–477*) very full discussion (1909) of the adult forms of the species and their taxonomic relationships leaves little to be desired. He especially emphasizes the salient type characters.

> Margins of the thorax and elytra broadly foliaceous and strongly reflexed, basal angles of the prothoracic margins projecting strongly backward over the basal angles of the elytra.

DISTRIBUTION

Nebraska: Alliance, altitude 3,971 feet, August, H. F. Wickham; Beaver City, altitude 2,150 feet, M. H. Swenk (*12*), September, J. S. Wade; "Nebraska," May to August, H. F. Wickham (*8*).

New Mexico: Chico, altitude 6,882 feet, September, D. J. Caffrey; Clovis, August, H. F. Wickham; Koehler, altitude 5,500 feet, June, V. L. Wildermuth, August, W. R. Walton; Vaughn, September, H. F. Wickham; Maxwell, altitude 5,894 feet, D. J. Caffrey; Willard, altitude 6,091 feet, H. F. Wickham.

Kansas: Clark County, altitude 1,962 feet, June, F. H. Snow (*10*); Colby, altitude 3,150 feet, August, J. S. Wade; Dodge City, altitude 2,509 feet, August, J. S. Wade; Hamilton County, altitude 3,000 feet, F. H. Snow (*10*); Liberal, altitude 2,839 feet,

July, J. S. Wade; Meade, altitude 2,503 feet, July, J. S. Wade; Morton County, altitude 3,000 feet, F. H. Snow (*10*); Norton, altitude 2,284 feet, August, J. S. Wade; Rice County, June, H. F. Wickham; Scott City, altitude 2,971 feet, August, J. S. Wade; Wallace County, altitude 3,000 feet, F. H. Snow (7); Wellington, altitude 1,205 feet, July, J. S. Wade; "Kansas to Texas," G. H. Horn (*5*), "Western Kansas: In Arkansas and Smoky Hill Valleys," E. A. Popenoe (*6*).

North Dakota: Dickinson, altitude 2,411 feet, August, H. F. Wickham; "Dakota," W. G. Dietz; "Dakota," May to August, H. F. Wickham (*8*).

Colorado: Bellevue, altitude 8,993, H. F. Wickham (*9*); Colorado Springs, altitude 6,072 feet, H. F. Wickham (*9*); Denver, altitude 5,279 feet, April, H. Soltau; Greeley, altitude 4,652 feet, June, H. F. Wickham; Fort Collins, altitude 4,994 feet, H. F. Wickham (*9*); LaSalle, altitude 4,676 feet, September, H. F. Wickham; Pueblo, altitude 4,685 feet, October, H. Soltau; West Las Animas, H. F. Wickham (*9*); "Colorado," May to August, H. F. Wickham (8).

Texas: Amarillo, altitude 3,676 feet, August, H. F. Wickham; Canadian, altitude 2,340 feet, August, H. F. Wickham; Mobeete, July, H. S. Barber; Texline, altitude 4,694 feet, September, I. R. Crawford.

Montana: Assinniboine Mountains, Hubbard and Schwarz; "Montana," May to August, H. F. Wickham (8).

South Dakota: Alexandria, altitude 1,354 feet.

Mexico: Nuevo Laredo, Tamaulipas, Hoge.

INJURY

The principal damage caused by these insects is that wrought by the larvæ during the fall in devouring recently sown or newly sprouted wheat grains shortly after the seed wheat has been drilled. These larvæ often may be found in large numbers in infested fields at such periods working steadily along through the soft soil of the drill rows, either wholly devouring or destroying for germination purposes every wheat grain within a drill row for many yards. Within the region of greatest infestation the principal injury is done between September 20 and October 15. The injury to the grain is characteristic of this family. Sometimes the entire contents of the grain are removed, leaving all or part of the shriveled outer husk; in some cases the ends of the grain are nibbled away or portions of the ventral crease are neatly furrowed out. The adults also are known to feed upon wheat grains and other seeds, being present around the bases of wheat stacks in July, where they may be found tearing away the spikelets of grain in newly cut wheat heads to devour the kernel within, or they may be found feeding upon the scattered grains. The extent of the injury varies annually in accordance with seasonal conditions, little or no damage being done in localities where an abundance of rainfall occurs, and where temperature and other factors are favorable to growing crops, whereas at the same time considerable loss may be experienced in other localities, varying from 10 to 50 per cent or more of the wheat of an entire neighborhood, where weather and other conditions render normal development of this crop impossible. In view of the fact that the larvæ of this pest usually may be found working with those of other nearly related species of true and false wireworms, it becomes increasingly difficult to isolate and estimate singly the exact amount of injury wrought by this particular pest.

HABITS

The larvæ are exceedingly active and quick and, if exposed to light by the plow or otherwise disturbed, have the power of wriggling very quickly down out of sight into the soil. They are also occasionally found upon the surface of the ground feeding upon seeds of weeds and of other plants, in spots where the soil may be slightly moist and where they are covered by wheat shocks or by matted masses of dried Russian thistles or other weeds. While they appear to prefer habitats where there may be a slight degree of moisture, such as moist, poorly drained spots in fields, and cool, damp cellars, yet they do not live long in thoroughly wet soil. Both larvæ and adults often may be found in numbers beneath dried weeds along irrigation canals. The larvæ habitually feed during warm weather at a depth varying from 2 to 5 inches, according to condition of the soil. As they burrow from place to place, they feed upon the roots and seeds of plants, and possibly to a certain extent upon organic matter where this is sufficiently decayed. When placed under artificial conditions the larvæ feed readily not only upon germinating wheat, but upon corn and roots of grasses. They are cannibalistic in that they feed upon other larvæ of the same species which die or become weakened because of injury or disease. They also feed upon their own exuviæ.

The adults, in common with those of other nearly related species, are very hardy and active and appear to be able to withstand considerable variations of temperature. While they, like the larvæ, appear to prefer cool, moist spots, they do not survive temperatures as low as −9° F. They have been collected in August beneath wheat shocks in fields where the temperature was as high as 100°. The adults easily climb all over wheat where standing or in the stack or shock, and they burrow with apparent ease far into the piles of unthrashed grain. They are also frequently found in the burrows of small mammals. During periods of prolonged drought the beetles may seem to have entirely disappeared, yet immediately following a shower or rainstorm, curiously enough they reappear in large numbers, where previously none could be found.

DESCRIPTIONS

EGG

Size slightly variable, being 1.1 to 1.3 mm. in length and 0.60 to 0.62 mm. in width; shape circular in cross section and oval in longitudinal section; without sculpturing; color pure white when first deposited, changing to yellowing brown before hatching.

MATURE LARVA [1]

Length 27 mm.; color testaceous with head and legs somewhat darker; anterior and posterior margins of prothorax and posterior margins of the following segments castaneous-testaceous. Surface corneous. Form elongately cylindrical, more than

[1] Description and Plates 31 and 32 by Adam G. Böving.

10 times longer than wide; dorsally very convex, ventrally flattened; pygidium movable in the directions up and down, subconical, obtusely pointed. Head, ventral sides of the thoracic segments and of the first abdominal segment, legs, and pygidium (Pl. 32, C) clothed with rigid or soft setæ; rest of body glabrous with very few and small ventral hairs.

Cranium (Pl. 31, B) rounded, nutant, exserted, one-third broader than long (from epistomal margin (*epi*) to foramen occipitale), broadest medianly, dorsally somewhat convex. Anterior frontal angle (*fa*) low and rounded. Frons (*f*) three-fourths the length of cranium, about as long as wide with extreme width anteriorly, side margin convex. Epicranial halves (*epc*) meeting dorsally; epicranial suture one-fourth the length of cranium; ventrally (Pl. 31, E) the halves are separated by gula (*gu*); dorsally with a few, laterally and ventrally with many hairs. Gula and submentum (*sm*) both distinct, coriaceous. Gula almost square, with tentorial pits (*tp*) at the middle of the side margins. Submentum trapezoidal, broadest posteriorly; side margins slightly concave and adjacent to maxillary articulating area. Clypeus (*cl*, Pl. 31, B) trapezoidal, widest behind, length to extreme width as one to four, medianly with slight transverse deepening, set on each side with one minute seta near the middle line and two well-developed setæ near the lateral margin. Labrum well-developed, movable, transversely rectangular, length to width as one to three, anterior margin almost straight, anterior corners rounded; disk on each half with a median transverse series of five large setæ, and an anterior series of three long, thin, and straight setæ; right behind those but on the ventral side of labrum another series of four shorter, stronger, and curved setæ. Epipharynx (*eph*, Pl. 31, A) forming the buccal surface of labrum, soft-skinned with posterior transverse, broad, sinuous, chitinous band, that carries one pair of stublike sharp teeth; on the soft-skinned part anteriorly to these teeth a pair of tiny hooks; near anterior margin scattered minute setæ and ring-shaped punctures. Just behind antenna two ophthalmic spots, both transverse, slightly posteriorly convex, the anterior a little more external and about three times longer than the posterior; immediately in front of the anterior are numerous setæ; the ophthalmic spots are likely to disappear in full-grown larvæ. Antenna (Pl. 31, B) closely behind the mandible, attached in articular cavity with distinct border; basal antennal membrane well developed; basal article cylindrical, about as long as epicranial suture, second article as long as basal article, more clavate, apical article very small, conical, papilliform, carrying one seta; no supplementary appendix besides the apical article. Mandibles (Pl. 31, F) of right and left side differing in shape; both apically bifid (a^1, a^2); both with one tooth (*t*) between apex and molar part (*m*); tooth of right mandible, however, prominent and placed near apex, that of left mandible less developed and placed closer to molar part; molar part of right mandible with bituberculate crown, that of left mandible with hollow crown; ventrally (Pl. 31, D) with cutting part deeply excavated; exterior surface ("the back of the mandible") distally with a slightly carinate margin (Pl. 31, F, *c*), proximally with a soft-skinned, whitish swelling (*s*) from an excavation (*e*) opposite the molar part; three to four strong setæ from the anterior portion of the swelling, two from the posterior, several small, soft setæ near dorsal mandibular articulation. Maxilla dorsally completely covered by mandible; palp (Pl. 31, E) surmounting mala (*ma*) (maxillary lobe) with one-third of its own length; palpiger (*pag*) small, ring-shaped; basal article about as wide as long, second article cylindrical, somewhat narrower and more than twice as long as basal article, apical article two-thirds as long and half as thick as the second, conical, with soft tip; each article with one or two thin setæ; mala (*ma*) on buccal surface (Pl. 32, F) with two series of well-developed, somewhat curved setæ; base of stipes (Pl. 31, E, *bs*) (that is, region where stipes and cardo meet) rather short; proximal half of inner margin of stipes (is_1) connected with exterior half of maxillary articulating area (ar^1), distal half (is_2) right behind mala, free; ventral stipital surface with several strong setæ; other setæ on the exterior surface; cardo as long as

exterior margin of stipes, adjacent to slightly curved hypostomal thickening (*hyp*) between fossa for ventral mandibular condyle (*fm*) and fossa for tip of cardo (*fc*); inner margin of cardo connected like stipes with exterior half (*ar* I) of maxillary articulating area. Maxillary articulating area protuberant, soft, divided into two halves; exterior half (*ar* I) connected with maxilla, subdivided into an upper and lower portion; interior half (*ar* II) connected with submentum, entire; no setæ. Mentum (*me*) almost square, side margins free; on each side about five setæ of different length. The two stipites labii (*stla*) fused into a slightly chitinized unit, carrying on each side two setæ; labial palp about half as long and half as thick as maxillary palp; basal and apical articles slightly different in length, basal article somewhat clavate, apical article conical and half as thick as basal article; ligula (*li*) small, narrow conical, with one terminal pair of setæ. Hypopharyngeal sclerite (Pl. 32, A, G, H, *hsc*) elongate rectangular, projecting, strong; anteriorly tricuspidate with median cusp largest; disk somewhat excavate with a posterior semiglobular tubercle; molar part of mandible and hypopharyngeal sclerite grinding together (Pl. 31, D, F, G). The hypopharyngeal bracon (Pl. 32, A, G, H, *hbr*) is well developed as a chitinous rod in the buccal membrane between the ventral mandibular articulation and the hypopharyngeal region. Prothoracic legs (Pl. 31, C, H, I; 32, B) considerably stronger than the mesothoracic and metathoracic ones and with coxæ attached so closely together that they almost touch each other at base. Coxa of first pair about as long as wide; many fine, scattered hairs on exterior and interior surfaces; trochanter about as long as coxa, on the inner side (Pl. 31, H) distally with two spinelike setæ and also with a few other thin hairs; femur (*fe*) about as long and wide as trochanter, armed with five spinelike setæ, also with many thin, scattered hairs; tibia (*ti*) about twice as long as thick, almost same length as femur but not fully as wide, armed with five spinelike setæ and also with fine, scattered hairs; tarsus (*ta*) of almost same length as tibia, claw-shaped, strong, but rather slender, with backward-facing surface distally excavate and proximally carrying a round soft-skinned region around a short but strong seta; another and similar seta set close to it at the end of the excavation; otherwise no setæ or hairs on tarsus. Second and third pairs of legs inserted farther apart than the first pair; the arrangement of their setæ very similar to that of the first pair, but the proportional sizes between the articles somewhat different from those of the first pair. Prothoracic eusternum (Pl. 32, B, *eu*) large, rhomboidal, anteriorly almost reaching the front margin of the segment, only separated from this margin by a small presternal area (*y*); the hypopleural chitinization (h_{I} and h_{II}), and especially its prehypopleural part (h_{I}), large and strong; prothoracic tergal shield subquadrate, slightly wider than long, with anterior and posterior margins, as mentioned above, darker than the rest of the shield and finely longitudinally striated. Mesothorax and metathorax with transverse, subtriangular, narrow presternum (*y*), laterally adjacent to poststernellum (*z*) of the preceding segment; hypopleural chitinizations (h_{I} and h_{II}) well developed, but considerably smaller than those of prothorax; poststernellum of metathorax not present, preepipleurum of mesothorax (e_{I}) subtriangular, carrying first thoracic spiracle; preepipleurum of metathorax not distinctly limited, carrying the rudimentary second thoracic spiracle; postepipleurum (e_{II}) of both segments well developed, more or less fused with the corresponding preepipleura; mesothoracic and metathoracic tergal shields transversal, subrectangular, about twice as wide as long, right behind anterior margin with a dark transverse line; posterior margin darker than rest of segment, finely longitudinally striated. Typical abdominal segment (that is, one of the eight anterior abdominal segments) with fused sternal and hypopleural areas (*ster*), covered by a single, longitudinally rectangular shield, which posteriorly has a rather dark, transverse, longitudinally finely striated margin; one seta present near the anterior and one seta near the posterior margin; additionally the sternum of first abdominal segment is anteriorly densely

set with small, soft setæ; similar outfit lacking on the other abdominal segments. Epipleural region narrow. Tergal region with a dark line above the spiracle. Tergal shield (*ter*) single, posteriorly with a dark, longitudinally striated margin. Anterior abdominal segments transverse, slightly wider than long; sixth, seventh, and eighth abdominal segments subquadrate. Ninth abdominal segment smaller than the preceding segment; dorsal part or pygidium pointing upwards, subconically produced, above somewhat flattened, below broadly convex, apex obtuse, laterally with margin set with a single series of strong, short setæ, whole surface with scattered, fine setæ; ventral part of ninth segment small, transverse, soft. Tenth abdominal segment (or "anal segment") small, with trilobate upper transverse anal lip, with a pair of conical and, except at the tip, setose ambulatory warts, laterally to anus a small triangular lower lip. Spiracles (Pl. 32, I) annular, shortly oval, transversely placed; opening at the bottom of cup-shaped peritrema, linear, unprotected by hairs. The number and development of setæ on the first pair of legs vary according to species and do not offer any generic character. The same is the case with the setal arrangement of pygidium.

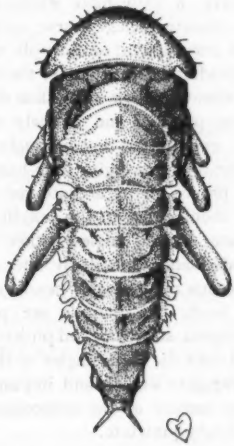

FIG. 1.—Pupa of *Embaphion muricatum*, dorsal view.

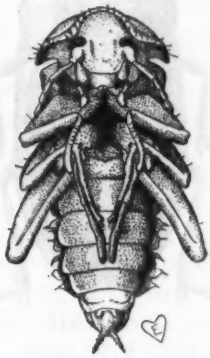

FIG. 2.—Pupa of *Embaphion muricatum*, ventral view.

PUPA (FIG. 1, 2)

Length 11 mm. Width 5.6 mm. Free. Arcuate. Color pinkish white, with ferruginous tinge on pronotum. Femora and tarsi fuscate, other appendages partly translucent. Pupa becomes more strongly colored immediately before issuance of adult. Head pressed to prosternum. Pronotum broad and projecting somewhat anterior to head, making the head nearly invisible from above. Frons impressed. Vertex prominent. Antennæ placed backward near sides of prothorax. Mesonotum narrow. Legs not pressed against body. Tips of wing cases extending to the anterior margin of metanotum. Second to fifth abdominal segments bearing on each side of tergites flat, lacerated protuberances, obtuse, pointed and directed posteriorly. Eighth segment ending in two slightly divergent, acute processes.

ADULT (FIG. 3) [1]

Oval to oblong-oval, brownish to piceous black, thoracic and elytral margins very broad and foliaceous, strongly reflexed.

Head small, less than twice as wide as long, plane, sides of the frons slightly prominent, punctate, punctures very feebly subasperate, fine, not dense, each with a small curved and short seta, frontal suture usually not visible. *Antennæ* rather long, quite slender, outer four joints very slightly compressed and scarcely widened, third joint shorter than the next two taken together, fourth scarcely longer than the fifth, the latter and sixth subequal, seventh shorter, eighth feebly shorter than the seventh and slightly triangular, ninth and tenth suborbicular, eleventh subovate.

Pronotum with margins very broadly foliaceous, the margin more than one-half wider than the *disc*, the latter comparatively narrow, longer than wide at middle, very feebly convex, usually with irregular depressed areas; finely, more or less subasperately and sparsely punctate; reflexed margins wider posteriorly and more or less concave, a little more distinctly punctate, punctures less sparse, each with a short curved seta; *apex* deeply and feebly subquadrately emarginate, the emargination about one-half wider than deep, sides almost parallel, and scarcely margined; *sides* evenly but not strongly arcuate, moderately converging from base to apex; *base* proper feebly arcuate, not margined and about equal to the length, lateral sinuate; apical angles rather narrowly rounded and formed by the advanced foliaceous margins and nearly as long as the head; basal angles are posteriorly prominent, subacute, and projecting backward over the basal angles of the elytra.

FIG. 3.—Adult of *Embaphion muricatum*, dorsal view.

Propleuræ smooth and impunctate; inferior surface of the foliaceous margins obsoletely punctate.

Elytra oval to elongate oval; *margins* broad and reflexed, angles at humeri nearly rectangular and more or less truncate at base, posteriorly extending beyond the apex, the two meeting on a line with the suture above the true elytral apex, and defined from the same by a slight groove, borders evenly arcuate from base to apex or more or less parallel basally; *base* evenly but not strongly emarginate; *humeri* proper broadly rounded and not prominent; *sides* proper more or less evenly arcuate; *apex* proper not produced and narrowly rounded; *disc* plane, feebly convex, at times slightly concave, the inflexed sides nearly straight and oblique, gradually and not strongly arcuately declivous behind; *surface* sculptured with approximate series of fine asperate punctures, which become more irregular and slightly denser laterally. Each puncture bears a short and rather robust curved seta.

Epipleuræ narrow, not attaining the humeral margin and not dilated, but gradually narrowing to apex, not defined from the inflexed sides of the elytra, and on the same plane; superior margin obsolete, except near apex; elsewhere represented by a line of punctures or a faint groove.

[1] Reprinted from F. E. Blaisdell (*11*, *p.* 473-476).

Sterna more or less dull, finely and not distinctly sculptured.

Parapleuræ smooth, rather sparsely but not very distinctly punctate.

Abdomen horizontal, very finely and sparsely punctulate, obsoletely rugulose and quite evenly convex.

Legs rather slender, moderate in length. Anterior femora mutic, protibial spurs similar in the sexes, the anterior slightly longer than the posterior. Protarsi simple.

LIFE HISTORY AND DEVELOPMENT

The principal observations on the life history and development of *Embaphion muricatum*, as given below, were made under laboratory and field conditions in south-central Kansas, at an altitude of approximately 1,200 feet. Under different conditions of latitude, altitude, and humidity there would doubtless be found more or less marked variations. The records are unfortunately based on incomplete studies for, owing to working conditions and to pressure of other duties, there was no opportunity to conduct a sufficiently extensive series of experiments to render all observations conclusive.

The eggs are deposited in loose, dry, or slightly moist soil at a depth of ½ to 1 inch, sometimes singly, but more often in clusters of two or three to a dozen or more eggs at one place. At temperatures ranging from 80° to 90° F. the average period of incubation is approximately 10 days, whereas at temperatures of 68° to 70° F. the egg stage is approximately 13 days. Undoubtedly weather conditions and the time of year have a direct bearing on the duration of the egg period.

During the later stages of development and shortly before hatching, the surface of the egg becomes light brown in color, and the shell appears to expand slightly and to become more flexible, while the movements of the young larva can be noted within. During the process of hatching, the struggles and the lifting pressure of the young larva burst the shell and the larva emerges by rather slow periodic movements, as its integument is very soft and fragile. Though the young larva often remains for some time near the place of hatching, yet it is capable of locomotion soon after emergence. All normal eggs of the same egg cluster usually hatch within a short period, generally a few hours. While abnormal weather conditions may prolong the period of hatching, no injurious effects of such retardation are noted in the eggs. No infertile eggs were ever collected under field conditions. Soon after the emergence of the larvæ the empty eggshells become more and more contracted and dried up, until eventually only tiny, shrivelled fragments remain.

Upon hatching the larva averages 3.5 to 3.75 mm. in length and is yellowish white. The color changes slightly after each molt until at maturity the larva becomes a deep yellow.

The length of the larva stage, according to an experiment consisting of 31 larvæ hatched in June and kept in a cool cellar at an average temperature of 68° F., averaged for the survivors 79 days, while in an experiment consisting of 49 larvæ, under similar conditions, it varied from 76 to

96 days, though the average duration was 85 days. The larvæ as hatched were placed in small tin salve boxes containing about ½ inch of slightly moist soil and split wheat grains. As the larvæ became large, whole wheat grains were used as food. Under field conditions many of the larvæ appear to become nearly mature during late fall and overwinter in this condition. From about November 1 to March 15 in the latitude of southern Kansas they are exceedingly inactive and feed but little. The rapidity of growth of the larvæ undoubtedly depends to a large degree upon weather and seasonal conditions and the quantity and quality of food available. Shortly before the period of pupation the larva does not feed and assumes a semidormant stage of approximately 7 to 9 days' duration.

The pupa stage, when rearings were conducted under laboratory conditions, comprised 18 to 20 days. The pupæ are pinkish white immediately after transformation, and as development proceeds the color changes to light yellow. Shortly before the adults emerge the appendages take on a yellowish brown tint.

The newly issued adults are of a brighter color, and the chitinous portions of the body are soft. Within a few days, however, the color darkens and the integument hardens so that the newly emerged adults are not distinguishable. Under artificial conditions mating does not become general for a week or more after emergence. Oviposition and feeding appear to occur usually at night. The adults are crepuscular. They may be found abroad in greatest numbers on cloudy days or in early morning or late evening. On clear days, during the middle or warmer portion of the day, they remain under shelter. While usually inactive at such periods, if disturbed they will run with great rapidity. The insect may overwinter both in the adult and in the larva stages. In the latitude of southern Kansas, however, the mortality of such overwintering adults is great.

ENEMIES

While the incomplete character of the life-history work performed with *Embaphion muricatum* afforded comparatively little opportunity for obtaining parasites under artificial conditions, or for obtaining data on other enemies for possible use in control work, yet some noteworthy information was obtained. From adults of *E. muricatum* collected by the writer from barley at Colby, Kans., on August 25 there were reared on October 23 adults of a parasite determined by A. B. Gahan of the Bureau of Entomology as *Perilitus eleodis* Viereck (*13*). No life-history work on these parasites was attempted.

Considerable difficulty was experienced in rearing larvæ owing to the presence in the cages of a fungus, *Metarrhizium anisoplae* Metsch. Soc.; and though the apparatus and soil were sterilized, yet the mortality was sufficient at times to interfere to a marked extent with the rearing. A

number of the larvæ in the cages were also attacked by an obscure bacterial disease. This appeared to be identical with that described by Prof. Swenk (*12*). There would appear somewhere upon the body sutures small circular or irregularly shaped dark brown spots, and these, after a few days, would become larger, until in some instances they would cover one-third to one-half of the body surface. This disease usually caused the death of the larvæ within varying periods of time. Larvæ found under normal field conditions are sometimes found to be affected both with Metarrhizium and with the disease.

CONTROL

While no extended series of experiments relative to control of the insect thus far has been found possible, yet the information secured on the subject has been sufficient to assure the practical value of the measures here recommended in reducing or preventing damage.

A systematic rotation of crops is one of the most effective procedures in cutting down damage. The maximum injury always may be found upon those areas where the ground has been cropped to wheat continuously for several years, whereas the minimum injury is found where corn, kafir, milo, and other crops are grown which require some degree of cultivation during the growing season. An important factor in migration and infestation lies in the fact that the beetles are wingless and therefore become dispersed much more slowly than do winged forms.

A number of fields within infested areas, which were also infested by the corn earworm (*Chloridea obsoleta* Fab.) and other insects of somewhat similar habits, were plowed by farmers during late fall or early spring to destroy the pupæ, and it was found that such measures were of considerable value in control of the false wireworms in the soil. The pupal cells were crushed and the pupæ buried or thrown out upon the surface, where they were exposed to the elements and to predatory enemies.

It is not only good farm practice but also advantageous as a control measure to destroy and remove from infested fields and adjacent fence rows all clumps of Russian thistles and other weeds or heavy growths of grasses likely to shelter these beetles.

While adults in small numbers are known to feed upon poisoned bran mash and similar preparations, experiments in poisoning the larvæ were not satisfactory. It appears doubtful that such poisoning will ever prove of practical value in dealing with this pest.

Late sowing of wheat in the fall also has been tried as a possible control measure, but does not appear to be successful unless the season is a very dry one, and even then if the seed has to lie in the ground any appreciable length of time before rain and germination much injury is likely to result, for the larvæ are most active in the dry, loose soil under such conditions.

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PLATE 31

Embaphion muricatum:

A.—Epipharynx (*eph*) and anterior margin of labrum.

B.—Head: *cl.*, clypeus; *fa*, anterior angle of front; *epi*, epistoma; *f*, frons; *epc*, epicranium.

C.—Lateral view of larva.

D.—Mandibles and hypopharyngeal sclerite from below. Concavity of molar part of left mandible grinding against the sclerite.

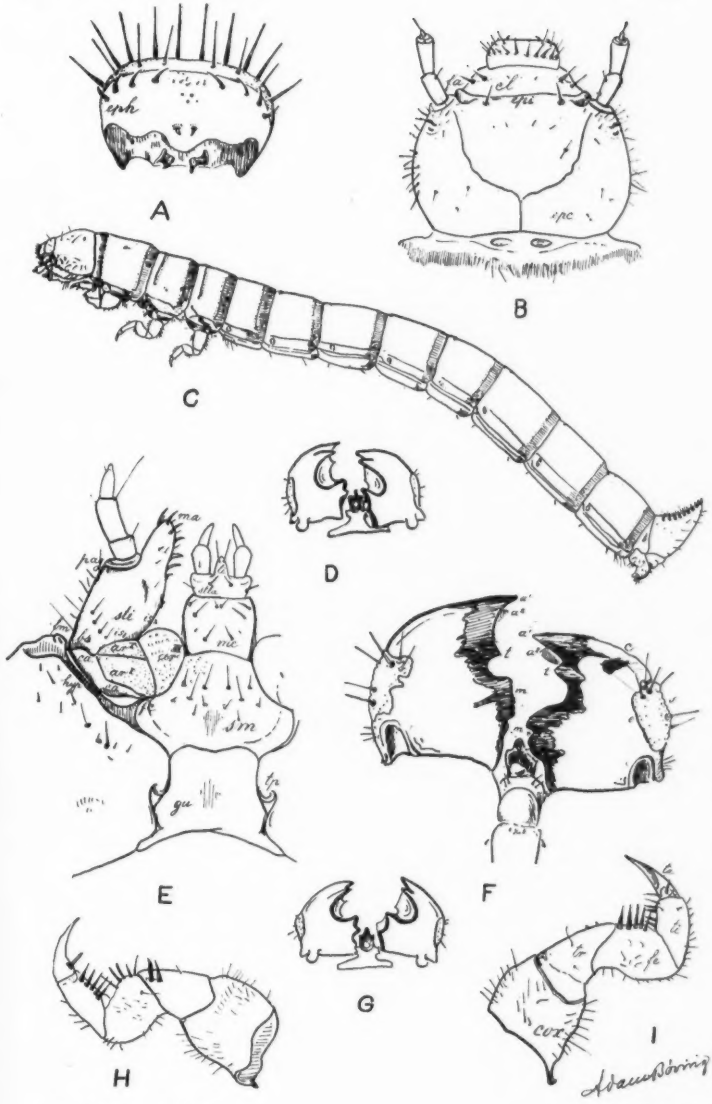
E.—Gula, labium, and right maxilla from ventral side: *gu*, gula; *tp*, tentorial pit; *sm*, submentum; *me*, mentum; *stla*, stipes labii; *li*, ligula; *hyp*, hypostoma; *fm*, fossa for mandible; *fc*, fossa for cardo; *ar*, maxillary articulating area; *ca*, cardo; *sti*, stipes maxillaris; *bs*, basis of stipes; is_1 and is_2, inner margin of stipes; *ma*, mala maxillaris (probably lacinia); *pag*, basal membrane of maxillary palp.

F.—Dorsal side of right and left mandible, hypopharyngeal sclerite between them: a^1 and a^2, the bicuspidate mandibular apex; *t*, tooth of cutting edge; *m*, molar part; *c*, carinate edge on exterior side of cutting part of mandible; *s*, soft-skinned, seta-bearing elevation below the carinate edge; *e*, margin of chitin framing the soft elevation.

G.—Mandibles and hypopharyngeal sclerite from below; no grinding in this position.

H.—Left anterior leg showing the anterior face of the leg hanging perpendicularly down from a horizontally placed larva.

I.—Left anterior leg, exhibiting its posterior face: *cox*, coxa; *tr.*, trochanter; *fe*, femur; *ti*, tibia; *ta*, claw-shaped tarsus, shortly but not correctly designated as "claw."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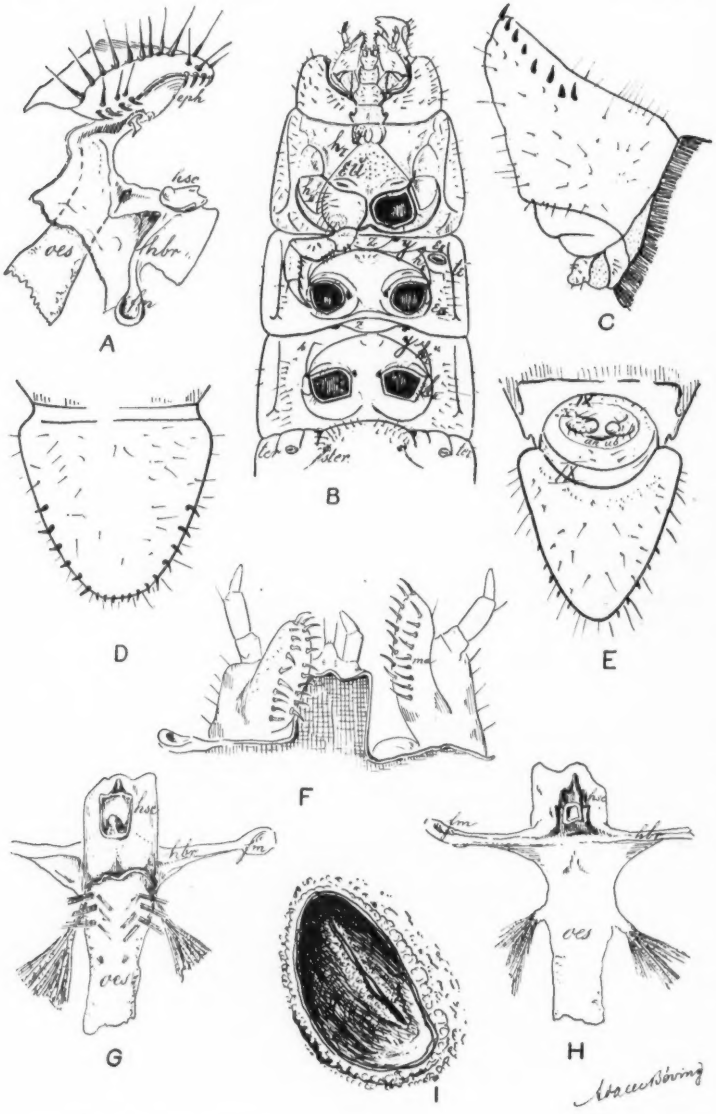
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PLATE 32

Embaphion muricatum:

A.—Lateral view of buccal cavity with mouthparts removed: *eph*, epipharynx; *hsc*, hypopharyngeal sclerite; *hbr*, hypopharyngeal bracon; *fm*, fossa of ventral condyle of mandible; *oes*, oesophagus (note the distance between sclerite and entrance to oesophagus).

B.—Ventral view of head, the thoracic segments, and the anterior portion of first abdominal segment: *y*, presternum; *eu*, eusternum (Snodgrass) or basisternum (Crampton); h_I, prehypopleurum; h_{II}, posthypopleurum; *z*, poststernellum (presternum and poststernellum constitute together the ventral intersegmental region); e_I, preepipleurum; e_{II}, postepipleurum; *te*, tergite; *ster*, sternal shield of abdominal segments; *ep*, abdominal epipleurum; *ter*, abdominal tergite.

C.—Pygidium, lateral view.

D.—Pygidium, dorsal view.

E.—Pygidium, ventral view; IX, ninth abdominal ("pygidial") segment; X, tenth abdominal ("anal") segment.

F.—Maxillæ, ligula, labial palpi seen from the buccal cavity. (Hypopharyngeal region removed.)

G.—Hypopharyngeal region, oesophagus, and hypopharyngeal bracon which all were removed from figure F: *hsc*, hypopharyngeal sclerite; *hbr*, hypopharyngeal bracon; *fm*, mandibular ventral fossa; *oes*, oesophagus.

H.—Hypopharyngeal region, same piece as figure G, reversed: *hsc*, base from which hypopharyngeal sclerite originates; *hbr*, hypopharyngeal bracon; *fm*, mandibular ventral fossa; *oes*, oesophagus.

I.—First thoracic spiracle.